Psychiatria Danubina, 2025 Vol. 37, No. 2, pp 132-140 https://doi.org/10.24869/psyd.2025.132 *Review article*

Importance of mental readiness in highly stressful professions

Krešimir Ćosić[1], Vanja Kopilaš[2] & Tanja Jovanović[3]

[1] Faculty of Electrical Engineering and Computing, University of Zagreb, Zagreb, Croatia
[2] University of Zagreb Faculty of Croatian Studies, Zagreb, Croatia
[3] Department of Psychiatry and Behavioral Neurosciences, Wayne State University School of Medicine, Detroit, MI, United States

received: 18. 2. 2025; revised: 13. 3. 2025; accepted: 3. 6. 2025

Summary

In highly stressful professions where decisions must be made under extreme pressure, mental readiness is a crucial factor in maintaining performance, safety, and long-term well-being. Professions such as aviation, emergency medicine, military service, and law enforcement require individuals as well as entire teams to navigate unpredictable, high-stakes situations where cognitive agility, emotion regulation, and stress resilience are essential. Without adequate mental preparedness, professionals and team members are more susceptible to impaired decision making, burnout, and psychological disorders, which can compromise both individual and organizational effectiveness. Despite its significance, mental readiness remains underemphasized in traditional selection and training programs, which often prioritize technical and physical skills. However, advancements in artificial intelligence (AI) and neuroscience offer new opportunities to enhance cognitive resilience. AI-driven predictive analytics, virtual reality (VR) training simulations, and biofeedback systems provide innovative methods for assessing and strengthening psychological preparedness. These technologies can help identify early signs of mental strain, optimize decision-making strategies, and develop personalized interventions to mitigate stress-related risks.

This paper explores the role of mental readiness in high-stress professions, emphasizing its impact on performance, safety, and mental health. It also examines emerging AI-based methodologies and psychological strategies designed to enhance resilience, improve decision making, and foster long-term occupational sustainability. By integrating these approaches, organizations can better prepare individuals and team members for the psychological demands of their roles, reducing the likelihood of stress-induced errors and improving overall professional effectiveness.

Keywords: *startle, resilience, work performance, artificial intelligence, occupational stress, job performance*

* * * * *

INTRODUCTION

In professions where the margin for error is razor thin and the consequences of failure can be life-altering, mental readiness becomes as critical as physical or technical expertise. Stressful professions, including but not limited to civilian and military pilots, first responders, neuro and cardiac surgeons, special forces, air traffic controllers, firefighters, and law enforcement demand exceptional mental fortitude and preparedness (Wiederhold, 2025). Individuals in these fields routinely confront unpredictable and high-stakes situations, including life-threatening emergencies, critical decision-making under pressure, and prolonged exposure to stress (Jacobs & Keegan, 2022). The ability to perform effectively and consistently in such environments is not merely a matter of technical proficiency or physical readiness; it is fundamentally linked to mental readiness. Moreover, early detection, prediction, and prevention of mental health deterioration in high-stress professions are essential to minimize the risk of incidents influenced by human factors (Ćosić et al., 2024a).

Mental readiness encompasses a range of psychological, physiological and cognitive attributes and skills, including resilience, adaptability, situational awareness, emotion regulation, and stress resilience (Marquardt et al., 2018, Ćosić, Popović, et al., 2012, Morrison and Fletcher, 2002). Cognitive components, such as attention control, memory recall, decision making speed, and executive functioning, play a pivotal role in enabling individuals to process information rapidly and respond effectively in high-pressure situations. These skills not only enable rapid decision-making but also ensure that individuals can recover from setbacks and perform effectively over time. Cognitive appraisal is one process by which individuals interpret and evaluate stressors (vonRosenberg, 2019). It is particularly important in high-risk scenarios, as it directly influences emotional and behavioral responses. Mental readiness is positively correlated to the feeling of confidence and being in control (McDonald et al., 1995). For example, surgeons must maintain unwavering focus during complex procedures, firefighters rely on rapid decision-making in unpredictable environments, and military personnel often operate under extreme conditions that demand both split-second judgment and emotional control (McDonald et al., 1995). A lack of mental readiness can lead to cognitive, emotional, and

behavioral problems, including impaired decision-making, heightened anxiety, and even maladaptive coping mechanisms. Mental readiness training has the potential to yield considerable preventative mental health advantages, likely establishing a higher baseline level of resilience, which could decrease the effects of chronic operational and organizational stressors (Ćosić, Srbljinović, et al., 2012). Research highlights the critical role of mental readiness in mitigating the adverse effects of occupational stressors, such as burnout, anxiety, depression, post-traumatic stress disorder (PTSD), and other mental health challenges (Arnsten, 2009; Ćosić, Popović, et al., 2012; Marquardt et al., 2018; McDonald et al., 1995; McEwen, 2007; Thompson & McCreary, 2006). Furthermore, fostering mental readiness contributes to improved team dynamics, better performance outcomes, enhanced long-term well-being and overall organizational performance and functioning, on individual and group levels (Bowers et al., 2017; Cosic et al., 2016; Davison et al., 2017).

Despite its evident importance, mental readiness is often overlooked in selection and preparation programs for high-risk professions. This gap in focus underscores the need for a more comprehensive approach to training and professional development—one that integrates mental readiness, as a core component alongside physical and technical competencies. This paper aims to explore the significance of mental readiness in high-risk professions, assessing its impact on performance, safety, and mental health outcomes. It will also discuss strategies to enhance mental readiness, including resilience training, stress inoculation, the incorporation of psychological support systems, and the potential of artificial intelligence (AI)-based technologies. By emphasizing the importance of mental readiness, this research seeks to contribute to a broader understanding of how to better prepare individuals for the demands of high-risk occupations, better performance and sustainable career to meet the mental demands of such job position, adapt successfully in the presence of extreme risk, and successfully continue tasks.

Mental readiness as a complex construct encompasses sub dimensions such as attentional control, goal setting, relaxation, activation, self-confidence, self-talk and imagery. It can be also seen as a set of personality traits, an assortment of skills or ways of behaving and thinking, or a combination of both personality traits and behaviors. States of mental readiness are related to all thoughts, feelings, beliefs, intentions, actions, memories, and perceptions, i.e., overall individual cognitive, emotional, physiological, or behavioral states, that are present at a given moment in time to successfully cope with startle as unexpected and unpredictable situations. Under extreme conditions, chaos and uncertainty, mental readiness is the ability to control variations in peak performance and retain rational judgment. People who are mentally ready can manage severe stress and grow mentally stronger due to factors such as character, behavior, resilience, cognitive skills and social acuity.

Research conducted in a variety of work settings such as sports, military and medicine, has integrated mental readiness dimensions to increase human performance in critical task episodes (Ćosić, Popović, et al., 2012; Krane, 1994; Marquardt et al., 2018; McDonald et al., 1995; Thompson & McCreary, 2006). High-stress professions—whether in healthcare, law enforcement, military, or other demanding fields—place a significant strain on mental endurance. These jobs require prolonged focus, quick decision-making, and the ability to remain calm under pressure. Over time, the mental toll of constant stress can lead to burnout, cognitive fatigue, and reduced performance. Maintaining mental readiness and endurance in high-stress professions is essential for long-term success and well-being. By developing coping strategies that strengthen mental readiness professionals can navigate the challenges of their jobs more effectively (Kent et al., 2018; Maresca et al., 2022).

MENTAL, COGNITIVE, EMOTIONAL AND BEHAVIORAL STATES

Each mental state corresponds to one or more specific dynamic state variables, such as neuronal firing rates or synaptic weights that describe specific dynamics of different neural networks. For example, these mental states might be related to valence and arousal, which are attributed to the dimensional model of emotional processes, or attributed to different cognitive processes, such as perceptions, attention, memories, or variables which encodes our visceral state (Thornton & Tamir, 2024). Mental states also represent internal, or endogenous, factors that shape human behavior, as well as moods, emotions, motivation which trigger actions, reasoning, and planning states (Thornton & Tamir, 2024).

Mental states during startle operations and processing of unexpected situations and events might be characterized by heightened alertness and vigilance caused by a sudden stressful event. The impact of startle on working memory, short-term and long-term memory, as well as a temporary break in memory can lead to difficulties in decision-making, which might be very high security risk (Diarra et al., 2023; Sarmiento et al., 2024). Additionally, repeated exposure to startling events can impact long-term cognitive

functions. Therefore, reliable monitoring of mental state during startle operations could help to prevent the potentially dangerous effects of stress. Mental readiness involves cognitive and emotional processes influenced by neurotransmitters and hormones (Salzman & Fusi, 2010). For example, norepinephrine enhances alertness in stressful situations, while dopamine boosts focus and motivation (McEwen, 2007). Serotonin stabilizes mood, supporting emotional resilience. Acetylcholine aids memory and learning, essential for cognitive function. Cortisol, in moderation, enhances alertness but can impair readiness if chronically elevated. Adrenaline prepares the body for immediate action, temporarily sharpening mental focus. The interplay between neurotransmitters and hormones affects mental readiness. For instance, stress hormones can alter neurotransmitter levels, impacting mood and cognitive function (Souza-Talarico et al., 2011). Therefore, maintaining a balance of these chemicals through lifestyle choices like exercise, diet, and mindfulness practices can help enhance mental readiness.

Emotion significantly influences cognitive functions such as perception, attention, learning, and problem-solving. High-stress situations can impair essential cognitive states needed for decision-making and planning, increasing the risk of critical errors. Negative emotions like fear and anxiety further disrupt performance (Cosic et al., 2024). Real-time monitoring of operational data during sudden or unexpected events is crucial for maintaining effective task execution. Cognitive state directly affects performance, including motor efficiency and decision making, making it a key area of research in fields such as surgery, firefighting, sports and driving (Dias et al., 2018; Frost et al., 2021; Hernandez-Mendo et al., 2019; Marquardt et al., 2018; McDonald et al., 1995). Various sensors, including electroencephalogram, functional near infrared spectroscopy, electrocardiogram, electromyogram, breathing rate monitors, and electrodermal activity sensors are used to assess physiological, emotional, and cognitive states in the laboratory but less so in real life situations.

During a startle response, sensory neurons triggered by sound, sight, smell, or vibration quickly signal potential threats, transmitting spikes from the sensory cortex to the amygdala, hypothalamus, and brainstem, ultimately reaching the locus coeruleus which releases norepinephrine, and increases alertness, attention, and stress responses (Hormigo et al., 2015; Naegeli et al., 2018). The locus coeruleus integrates input from various brain areas, including the hypothalamus and cortex, to manage stress and arousal signals. The amount of norepinephrine released is linked to how a threat is perceived, influencing responsiveness (Haas & George, 1989). However, excessive norepinephrine release, particularly in response to prolonged stress, can impair higher cognitive functions in the prefrontal cortex, prompting instinctual reactions (Bouras et al., 2023). Chronic activation of the locus coeruleus can lead to sustained high norepinephrine levels, contributing to anxiety, fear, and intrusive memories, and may increase the risk of post-traumatic stress disorder and depression (Borodovitsyna et al., 2018; Bouras et al., 2023; Naegeli et al., 2018).

The prefrontal cortex (PFC) is essential for higher-order cognitive functions and is highly sensitive to the effects of stress. Even mild acute stress can quickly impair prefrontal cognitive abilities, while prolonged stress can cause structural changes in the PFC (Arnsten, 2009).

These effects are particularly significant in high-pressure situations where PFC-mediated abilities, such as decision-making and task management, are crucial for success. The PFC is extensively connected to other brain regions that regulate emotions, motor actions, attention, and error monitoring. It also links to areas like the locus coeruleus, substantia nigra, and ventral tegmental area, which regulate norepinephrine and dopamine release (Salzman & Fusi, 2010). Under stress, the amygdala activates stress pathways that increase these neurotransmitters, weakening PFC regulation and enhancing the amygdala's influence, which can impair emotional control and decision-making (Arnsten, 2009). The PFC integrates information from both external and internal sources, including emotions and cognitive plans, making it vital for maintaining mental readiness (Friedman & Robbins, 2022; Salzman & Fusi, 2010). As such, comprehensive mental readiness training is essential to prevent exaggerated stress responses and cognitive decline through improved PFC activity, enhancing situational awareness and performance across various operational scenarios.

Different emotional states have a particularly strong impact on attention, modifying its selectivity in particular and influencing behavior and action motivation. The amygdala is most often discussed in the context of emotional processes since it is extensively interconnected with the PFC, especially the posterior orbitofrontal cortex, and the anterior cingulate cortex (Salzman & Fusi, 2010). Sensory input reaches the amygdala from higher-order visual, auditory, and somatosensory cortices, while its output extends to various target structures, including the PFC, striatum, sensory cortices, hippocampus, and subcortical regions that regulate autonomic and hormonal responses linked to emotion. Emotions vary along two key dimensions: valence (positive vs. negative) and intensity (arousal). These factors are strongly encoded in the interaction between the amygdala and prefrontal circuits (Salzman & Fusi, 2010).

Integration and interaction among mental, cognitive and emotional states determine human mental readiness

as function of time. A crucial element of cognitive-emotional interaction is the growing evidence that cognitive processing is influenced by and operates alongside emotional processing. Notably, key brain regions involved in emotional processing include the amygdala, cingulate cortex, orbitofrontal cortex, and mid-ventral prefrontal cortex (Seitz, 2022). Appropriate ontology or taxonomy for smart fusion of all these mental states and processes could be extremely important and tricky research topic since for example, stress and mental workload are sometimes difficult to disentangle due to the similarity of their physiological indicators like increase in heart rate (Causse et al., 2024).

ARTIFICIAL INTELIGENCE IN MENTAL READINESS ASSESSMENT

In recent years, advancements AI have presented new opportunities to enhance mental readiness in stressful professions. AI-driven tools, such as predictive analytics, virtual reality (VR) training simulations, and biofeedback systems, offer innovative ways to assess, train, and monitor cognitive and psychological preparedness. Early identification and monitoring of individuals with low stress resilience are crucial to preventing long-term mental health disorders. The treatment of mental disorders, their prevention, and the promotion of mental well-being are three essential pillars of modern psychiatry (Jakovljevic, 2023). AI-based predictive methodologies integrate multimodal neuro-psycho-physiological data sets to assess mental health risks, detect suicidal ideation, and enhance automated treatment delivery. By leveraging diverse data sources, such as brain imaging, biomarkers, and social media activity, AI has the potential to transform psychiatry from predominantly pharmacotherapy to a more data-driven, analytic discipline, improving early detection and prevention strategies for vulnerable individuals (Ćosićet al., 2020). AI can be utilized to create personalized training programs that simulate high-stress scenarios tailored to specific professions such as law enforcement, healthcare, military service, air traffic control, and firefighting (Ćosić et al., 2024a; Wiederhold, 2025). For instance, AI-powered VR simulations allow emergency responders to practice handling high-stress scenarios in a controlled environment, building their resilience before facing real-life challenges (Bernardo, 2017; Haase et al., 2004). In other examples, neuro and cardiac surgeons can use VR simulations to practice rare and high-stakes procedures, while firefighters can engage in AI-designed drills that replicate hazardous scenarios (Alaraj et al., 2011; Bernardo, 2017; Haase et al., 2004).

VR therapy is an innovative tool in psychiatry, offering controlled and immersive environments for treating anxiety disorders, PTSD, eating disorders, and addiction (Maples-Keller et al., 2017). By enabling graded exposure, cognitive restructuring, and guided visualization, VR enhances traditional psychotherapeutic techniques while improving patient engagement and treatment outcomes (Dilgul et al., 2020; Maples-Keller et al., 2017). AI systems could monitor stress levels and provide interventions in real time to maintain peak performance. Assessing mental readiness during exposure to startle-based operations—high-intensity, sudden events that require immediate action—can involve AI-based tools that measure physiological responses, such as heart rate variability and skin conductance response, alongside cognitive assessments of situational awareness and decision-making speed (Endsley, 1995). Additionally, AI-powered mental health support systems can provide real-time feedback and interventions, helping to address stress and fatigue before they impact performance (Cornet & Holden, 2018). High-stress professions, such as law enforcement, healthcare, military service, civilian and military pilots, air traffic controllers, and firefighting demand rigorous mental health evaluations and innovative therapeutic approaches to maintain psychological resilience and operational readiness. Cutting-edge tools, including AI-based predictive models, personalized treatment strategies, and VR therapy, hold great potential for identifying and addressing stress-related disorders before they escalate. By adapting evidence-based interventions like cognitive-behavioral exposure therapy, stress inoculation training, and emotion regulation techniques, these methods can enhance coping mechanisms, improve mental readiness, and support long-term well-being in high-risk occupational settings (Ćosić et al., 2024a).

Mental readiness as complex brain-body interactions can be assessed by comprehensive multimodal neuro-physiological measurements and appropriate task objective defined as the difference between ideal, needed or expected task performance, and reality. Different task conditions, such as high mental workload, physical or mental stress, distracted attention, fatigue, excessive workload, decline of performance, loss of confidence, or situational disorientation can significantly impair human cognitive functions and decision-making abilities leading to human performance degradation. Assessment of mental readiness during unpredictable and unexpected stressful operations requires real time synchronization of data related to human neuro-psycho- physiological features and corresponding environmental conditions related to specific objectives or task performance. This synchronicity among all relevant real time input information is extremely important for accurate computation of mental readiness

which must be preserved during computation time. Real time cross-correlation analysis of human multimodal physiological, emotional and cognitive fluctuations with ongoing changes of operational context and task complexity is critically important for realistic semantic interpretations of individual's functional states and mental readiness. For example, in aviation, a pilot's semantic interpretation of all flight parameters, such as flight weather conditions, operational and tactical situations, and situational awareness, is critically important for evaluation of their flight performance. Increases in heart rate during steady state stationary flight could be used to signal potential pilot mental stress or overload, while normal heart rate increase is usually associated with take-off and landing. Therefore, context analysis is extremely important for correct interpretation of different physiological fluctuations and appropriate thresholds or limits for each neuro-physiological state variable during some specific operational conditions. Using the above example, a heart rate increase over a predefined baseline limit of what is expected during landing could be used to signal difficulties that may require specific alarm or intervention by air traffic control. Understanding interactions of all these neuro-psycho-physiological multimodal features within specific flight environments is crucial for developing strategies for how to manage and mitigate the negative impact of startle situations, especially for pilots who are operating in highly stressful unpredictable and unexpected flight conditions. Therefore, synchronized consideration of flight context, pilots' mental states and their performance in real time are a prerequisite for the reliable estimation of pilots' mental readiness. Real time neurophysiological measurements and their contextual interpretation may detect drift towards safety boundaries and risky performance or operators' functional states which may lead to potential disaster.

New wearable noninvasive technologies available today offer a tremendous opportunity to acquire human's multimodal neuro-psycho-physiological signals for assessing their mental readiness. Continuous and comprehensive real time monitoring of complex physiological parameters using a wide range of wearable sensors which enable accurate identification of challenging physiological, emotional and cognitive states. Various sensors monitor physiological and behavioral states. Electrodermal activity (EDA) or skin conductance response (SCR) tracks skin conductance associated with sympathetic vs parasympathetic activity (Posada-Quintero & Chon, 2020). Electrocardiogram (ECG) records heartbeats, while electroencephalogram (EEG) and electromyography (EMG) detect brain, muscle, and nerve activity. Photoplethysmography (PPG) estimates heart rate and blood oxygen levels (Dzedzickis et al., 2020). Respiratory belts (RB) track breathing, and electrooculogram (EOG) monitors eye movements. Accelerometers, gyroscopes, and magnetometers capture body movement. Modern technology utilizes up to 1,200 digital sensors to analyze 8,000 physiological and behavioral features, enabling advanced machine learning applications in health and behavior analysis (Dang et al., 2023; Sabry et al., 2022). Longitudinal tracking and monitoring of human multimodal neuro-psycho-physiological features are a valuable source of information for prediction of human mental readiness and functional performance during stressful startle operations (Cosic et al., 2019).

Machine and deep learning methods can significantly enhance the prediction of human mental readiness and performance by analyzing complex patterns of large neuro-psycho- physiological datasets, considering operational context and human performance during startle operations (Chen et al., 2022; Garriga et al., 2022; Le Glaz et al., 2021; Sabry et al., 2022). These predictive models can be continuously retrained with real time data, improving accuracy and adaptability in dynamic environments. Using machine learning and deep learning (ML/DL) algorithms, such models can predict individual mental readiness and performance by evaluating nonlinear relationships between contextual conditions, human reactions, and mental states, helping to prevent errors or failures. Various algorithms, such as Support Vector Machines, Random Forests, and Recurrent Neural Networks, are employed to create these models, while traditional methods like fuzzy logic may offer advantages for real time applications requiring speed and precision (Sarker, 2021). The ML/DL models should be continually trained and updated with new multimodal neurophysiological data during specific task execution. Domain knowledge related to specific task, job or mission is essential for the model's accuracy. However, the inclusion of irrelevant features can reduce model accuracy, emphasizing the importance of selection of only domain relevant features, for example, heart rate, breathing rate, and motion acceleration features.

DISCUSSION

This article builds upon our long-standing research on various aspects of mental health, related to stress resilience, VR and AI applications (Beroš et al., 2021; Ćosić et al., 2010, 2018; Cosic et al., 2019, 2020; Ćosić et al., 2020, 2021; Cosic et al., 2024; Ćosić et al., 2024b, 2024a; Ćosić, Popović, et al., 2012; Ćosić, Srbljinović, et al., 2012; Kopilaš, 2019; Kurtak et al., 2024). Conducted in collaboration with academic institutions such as Emory University School of Medicine, Hadassah Hebrew

University, Wayne State University School of Medicine, Harvard University, and Massachusetts General Hospital, our research has been focused on high-risk professions, such as military special forces, air traffic controllers, and pilots (Cosic et al., 2019; Cosic et al., 2024). These projects have been funded by NATO's *Science for Peace Program*, *European Defence Fund* among others.

Unfortunately, the lack of mental readiness is often overlooked as a key risk factor, and can be the main cause in many tragic accidents related to highly stressful professions and occupations during unpredictable and unexpected events or situations. Therefore, mental readiness, particularly among those at high risk due to high workload, fatigue, or exhaustion, are crucial to minimize potential tragic incidents and consequence caused by human factors. Their overloaded, stressful professional lifestyle and inadequate rest can disrupt circadian rhythms, leading to fatigue, burnout, anxiety, depression, chronic stress and potentially culminating in posttraumatic stress disorder in the event of trauma exposure. The long-term consequences of such states can adversely affect overall performance, behavior and decision-making processes, potentially leading to tragic accidents and loss of life**.**

Contextual features may also include valence and arousal as components of the dimensional emotional model, like level of perceived stress, i.e., emotional context of current situation and its changes during startle operations. Reliable and accurate expert labeling or annotation of valence and arousal during different flight conditions is important for training of corresponding ML/DL models, enabling deeper semantic understanding of startle dynamic complexity. Dynamics of these variations and their cross-correlation with neuro-psycho- physiological changes and human performance determine the level of their mental readiness. The difference between expected states and conditions and unexpected startle events can cause proportional activation of stress-related brain networks. For example, such startle events can release dopamine and norepinephrine influx towards cortical structures, particularly parietal cortex which is in charge in cooperation with prefrontal structures for situational awareness. Consequentially, the limbic network induces hyperactivation of the sympathetic nervous system and proportional neuro-psycho-physiological feedback which can be measured in real time. Prestartle, startle and post-startle fluctuations of an individual's multimodal neurophysiological feedback illustrate variations of their emotional states, such as fear, stress, anxiety, and cognitive appraisal, including attention tunneling, distracted attention, and cognitive overload. In order to get a better and deeper understanding of operational contexts and situational awareness during unpredictable and unexpected startle situations we need stronger support and assistance of state- of-the-art tools and means of artificial intelligence, particularly generative AI.

AI-driven predictive methods can detect early signs of psychological problems, enabling timely interventions to prevent severe mental health conditions in high-stress occupations. Explainable AI can serve as an intuitive digital assistant, identifying specific patterns and subtle warning signs of mental decline, thus facilitating prompt prevention and intervention. Longitudinal tracking of neuro-psycho-physiological responses could help predict stress resilience, mental health disorders, and performance under stress, which are crucial for task safety. Monitoring their cognitive, emotional, and behavioral states during startle operations could identify individuals at risk of acute or chronic mental health issues. Using AI and ML to analyze these data may allow early detection of mental health problems and the selection of individuals for preventive training or treatments. This approach could reduce unexplained tragic events linked to human factors and mental health. Continuous monitoring of their physiological data, combined with preventive treatments like cognitive-behavioral therapy, mindfulness, and stress inoculation training, should be integral to mental health strategies.

State of the art technology based on wearable digital sensors, digital therapeutic apps and new AI and ML tools and means may provide tremendous opportunities to improve a continuum of mental health and well-being in highly stressful professions, encompassing stress inoculation training, prediction, prevention and treatment. A variety of wearable devices, like smart watches, armbands, wristbands, chest straps, shoes, helmets, glasses, lenses, rings, textiles, and hearing aids can collect huge amounts of data which might be used by a variety of ML methods, like deep neural networks for training and predictive modeling of human mental states. The complexity of these applications may require high computational power, particularly with an increased number of customized multisensory inputs and modalities, numerous neuro-psycho-physiological features and sophisticated ML training algorithms. Therefore, these applications will require sufficient distributed processing power, an adequate amount of memory, high-speed interfaces capable of moving large amounts of data, multisensory and multimodal input-output interaction devices, etc. Such applications need immediate analysis and processing of large data sets, timely decisions, and accurate decision-making.

Usage of distributed architectures and cloud computing related to analysis of big data sets on multiple hierarchical levels, as along with advanced ML algorithms and advanced analytics, may provide accurate and insightful identification of individuals with compromised mental health. While cloud computing offers the flexibility of

storage and computational resources on- demand, it comes with compromises in higher costs, power consumption, latency, and challenges for preserving the privacy of both the data and the ML model. If the sensor data is stored on centralized servers with personally identifiable information about an individual's mental health, and if that information is hacked, the individual's privacy might be compromised. Therefore, acquiring and processing sensory data on local devices keeps the data private and decreases the latency for the prediction/classification, because there is no need to transmit large amounts of data from edge devices to the cloud outside of the user's control. However, this cloud-edge computing architecture depends on specific applications, the size of the data streams and ML models to be used in training and testing.

CONCLUSION

Continuous and comprehensive monitoring of complex human physiological parameters using a wide range of wearable sensors enables the early identification of compromised physiological and cognitive states**.** This approach offers several advantages, such as improved safety and security, better healthcare management and an enhancement in performance quality, life satisfaction, and overall well-being. Recent literature suggests that improving mental health care and safety management, supported by AI-based tools and methods, should be a fundamental part of a stronger prevention strategy to avoid the serious consequences of mental health decline within highly stressful professions (Ćosić et al., 2020; Cosic et al., 2024; Ćosić et al., 2024b; Thakkar et al., 2024). The capacity to make faster and more accurate predictions is crucial for stopping the progression from acute stress to severe chronic disorders like PTSD or burnout. This is especially important for individuals in high-risk, high-stress roles with constant cognitive demands. Timely predictive modeling could, therefore, be lifesaving for employees dealing with significant mental health challenges. As technology continues to advance, bringing more processing power, larger data storage capacities, a wider range of sensors, more sophisticated AI and ML algorithms, and improved prediction accuracy, we have the opportunity to design, develop, and validate more advanced multi-purpose, cost-effective capabilities. These capabilities can facilitate immediate alerting, stress detection and stress management, positively impacting on safety and security of such professional occupations.

Ethical Considerations: Does this study include human subjects? NO
Conflict of interest: No conflict of interest
Funding sources: The authors received no funding from an external source
Authors Contributions: Krešimir Ćosić: conception or design of the study, acquisition of the data, analysis or interpretation of data, drafting of the manuscript, critical revision of the manuscript for vital intellectual content, final approval of the version to be submitted, agreement to be accountable for all aspects of the work. Vanja Kopilaš: acquisition of the data, analysis or interpretation of data,critical revision of the manuscript for vital intellectual content, final approval of the version to be submitted, agreement to be accountable for all aspects of the work. Tanja Jovanović: acquisition of the data, analysis or interpretation of data, critical revision of the manuscript for vital intellectual content, final approval of the version to be submitted, agreement to be accountable for all aspects of the work.

REFERENCES

Alaraj, A., Lemole, M., Finkle, J., Yudkowsky, R., Wallace, A., Luciano, C., Banerjee, Pp., Rizzi, S., & Charbel, F. (2011). Virtual reality training in neurosurgery: Review of current status and future applications. *Surgical Neurology International*, *2*(1), 52. https://doi.org/10.4103/2152-7806.80117

Arnsten, A. F. T. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience, 10(6),* 410-422. https://doi.org/10.1038/nrn2648

Bernardo, A. (2017). Virtual Reality and Simulation in Neurosurgical Training. *World Neurosurgery*, *106*, 1015-1029. https://doi.org/10.1016/j.wneu.2017.06.140

Beroš, K., Brajković, L., & Kopilaš, V. (2021). Psychological resilience and depression in women with anorexia nervosa. *Mediterranean Journal of Clinical Psychology*, *9*(1), 2021. https://doi.org/10.6092/2282-1619/mjcp-2662

Borodovitsyna, O., Joshi, N., & Chandler, D. (2018). Persistent Stress-Induced Neuroplastic Changes in the Locus Coeruleus/ Norepinephrine System. *Neural Plasticity*, *2018*, 1-14. https://doi.org/10.1155/2018/1892570418

Bouras, N. N., Mack, N. R., & Gao, W.-J. (2023). Prefrontal modulation of anxiety through a lens of noradrenergic signaling. *Frontiers in Systems Neuroscience*, *17*. https://doi.org/10.3389/fnsys.2023.1173326

Bowers, C., Kreutzer, C., Cannon-Bowers, J., & Lamb, J. (2017). Team Resilience as a Second-Order Emergent State: A Theo-

retical Model and Research Directions. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.01360

Causse, M., Mouratille, D., Rouillard, Y., El Yagoubi, R., Matton, N., & Hidalgo-Munoz, A. (2024). How a pilot's brain copes with stress and mental load? Insights from the executive control network. *Behavioural Brain Research*, *456*, 114698. https://doi.org/10.1016/j.bbr.2023.114698

Chen, Z. S., Kulkarni, P. (Param), Galatzer-Levy, I. R., Bigio, B., Nasca, C., & Zhang, Y. (2022). Modern views of machine learning for precision psychiatry. *Patterns*, *3*(11), 100602. https://doi.org/10.1016/j.patter.2022.100602

Cornet, V. P., & Holden, R. J. (2018). Systematic review of smartphone-based passive sensing for health and wellbeing. *Journal of Biomedical Informatics*, *77*, 120-132. https://doi.org/10.1016/j.jbi.2017.12.008

Cosic, K., Kopilas, V., & Jovanovic, T. (2024). War, emotions, mental health, and artificial intelligence. *Frontiers in Psychology*, *15*. https://doi.org/10.3389/fpsyg.2024.1394045

Ćosić, K., Popović, S., Kovač, B., Horvat, M., Kukolja, D., Dropuljić, B., Fabek, I., Lolić, Z., & Popović, B. (2012). The Concept for Assessment of Pilot Mental Readiness Training. *54th Conference of the International Military Testing Association (IMTA 2012)*.

Ćosić, K., Popović, S., Kukolja, D., Horvat, M., & Dropuljić, B. (2010). Physiology-Driven Adaptive Virtual Reality Stimulation for Prevention and Treatment of Stress Related Disorders. *Cyberpsychology, Behavior, and Social Networking*, *13*(1), 73-78. https://doi.org/10.1089/cyber.2009.0260

Cosic, K., Popovic, S., Sarlija, M., & Kesedzic, I. (2020). Impact of human disasters and covid-19 pandemic on mental health: potential of digital psychiatry. *Psychiatria Danubina*, *32*(1), 25-31. https://doi.org/10.24869/psyd.2020.25

Ćosić, K., Popović, S., Šarlija, M., Kesedžić, I., Gambiraža, M., Dropuljić, B., Mijić, I., Henigsberg, N., & Jovanovic, T. (2021). AI-Based Prediction and Prevention of Psychological and Behavioral Changes in Ex-COVID-19 Patients. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.782866

Ćosić, K., Popović, S., Šarlija, M., Kesedžić, I., & Jovanovic, T. (2020). Artificial intelligence in prediction of mental health disorders induced by the COVID-19 pandemic among health care workers. *Croatian Medical Journal*, *61*(3), 279-288. https://doi.org/10.3325/cmj.2020.61.279

Ćosić, K., Popović, S., & Wiederhold, B. K. (2024a). Enhancing Aviation Safety through AI-Driven Mental Health Management for Pilots and Air Traffic Controllers. *Cyberpsychology, Behavior, and Social Networking*, *27*(8), 588-598. https://doi.org/10.1089/cyber.2023.0737

Ćosić, K., Popović, S., & Wiederhold, B. K. (2024b). Enhancing Aviation Safety through AI-Driven Mental Health Management for Pilots and Air Traffic Controllers. *Cyberpsychology, Behavior, and Social Networking*. https://doi.org/10.1089/cyber.2023.0737456

Cosic, K., Sarlija, M., Ivkovic, V., Zhang, Q., Strangman, G., & Popovic, S. (2019). Stress Resilience Assessment Based on Physiological Features in Selection of Air Traffic Controllers. *IEEE Access*, *7*, 41989-42005. https://doi.org/10.1109/ACCESS.2019.2907479

Cosic, K., Srbljinović, A., & Popović, S. (2016). Multidisciplinary metrics on individual and societal stress resilience. *2nd International Symposium on Resilience Research Mainz*.

Ćosić, K., Srbljinović, A., & Popović, S. (2018). Emotionally Based Strategic Communications in the Process of Societal Deradicalization. *International Journal of Strategic Communication*, *12*(2), 196-214. https://doi.org/10.1080/1553118X.2018.1426587

Ćosić, K., Srbljinović, A., Popović, S., Wiederhold, B. K., & Wiederhold, M. D. (2012). Emotionally Based Strategic Communications and Societal Stress-Related Disorders. *Cyberpsychology, Behavior, and Social Networking*, *15*(11), 597-603. https://doi.org/10.1089/cyber.2012.0410

Dang, T., Spathis, D., Ghosh, A., & Mascolo, C. (2023). Human-centred artificial intelligence for mobile health sensing: challenges and opportunities. *Royal Society Open Science*, *10*(11). https://doi.org/10.1098/rsos.230806

Davison, S., Raison, N., Khan, M. S., Dasgupta, P., & Ahmed, K. (2017). Mental training in surgical education: a systematic review. *ANZ Journal of Surgery*, *87*(11), 873-878. https://doi.org/10.1111/ans.14140

Diarra, M., Marchitto, M., Bressolle, M.-C., Baccino, T., & Drai-Zerbib, V. (2023). A narrative review of the interconnection between pilot acute stress, startle, and surprise effects in the aviation context: Contribution of physiological measurements. *Frontiers in Neuroergonomics*, *4*. https://doi.org/10.3389/fnrgo.2023.1059476

Dias, R. D., Ngo-Howard, M. C., Boskovski, M. T., Zenati, M. A., & Yule, S. J. (2018). Systematic review of measurement tools to assess surgeons' intraoperative cognitive workload. *British Journal of Surgery*, *105*(5), 491-501. https://doi.org/10.1002/bjs.10795

Dilgul, M., Martinez, J., Laxhman, N., Priebe, S., & Bird, V. (2020). Cognitive behavioural therapy in virtual reality treatments across mental health conditions: a systematic review. *Consortium Psychiatricum*, *1*(1), 30-46. https://doi.org/10.17650/2712-7672-2020-1-1-30-46

Endsley, M. (1995). A Taxonomy of Situation Awareness Errors. In R. Fuller, N. Johnston, & McDonald N. (Eds.), *Human Factors in Aviation Operations* (pp. 287-292). Ashgate Publishing Ltd.

Friedman, N. P., & Robbins, T. W. (2022). The role of prefrontal cortex in cognitive control and executive function. *Neuropsychopharmacology*, *47*(1), 72-89. https://doi.org/10.1038/s41386-021-01132-0

Frost, C., Toczko, M., Merrigan, J. J., & Martin, J. R. (2021). The effects of sleep on firefighter occupational performance and health: A systematic review and call for action. *Sleep Epidemiology*, *1*, 100014. https://doi.org/10.1016/j.sleepe.2021.100014

Garriga, R., Mas, J., Abraha, S., Nolan, J., Harrison, O., Tadros, G., & Matic, A. (2022). Machine learning model to predict mental health crises from electronic health records. *Nature Medicine*, *28*(6), 1240-1248. https://doi.org/10.1038/s41591-022-01811-5493

Haas, D. A., & George, S. R. (1989). Neuropeptide Y-induced effects on hypothalamic corticotropinreleasing factor content and release are dependent on noradrenergic/adrenergic neurotransmission. *Brain Research, 498(2),* 333-338. https://doi.org/10.1016/0006- 8993(89)91112-8

Haase, J., Musaeus, P., & Boisen, E. (2004). Virtual Reality and Habitats for Learning Microsurgical Skills. In *Virtual Applications* (pp. 29-48). Springer London. https://doi.org/10.1007/978-1-4471-3746-7_3

Hernandez-Mendo, A., Reigal, R. E., Lopez-Walle, J. M., Serpa, S., Samdal, O., Morales-Sanchez, V., Juarez-Ruiz de Mier, R., Tristan-Rodriguez, J. L., Rosado, A. F., & Falco, C. (2019). Physical Activity, Sports Practice, and Cognitive Functioning:

The Current Research Status. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02658

Hormigo, S., Gomez-Nieto, R., Castellano, O., Herrero-Turrion, M. J., Lopez, D. E., & de Anchieta de Castro e Horta-Junio, J. (2015). The noradrenergic projection from the locus coeruleus to the cochlear root neurons in rats. *Brain Structure and Function*, *220*(3), 1477-1496. https://doi.org/10.1007/s00429-014-0739-3

Jacobs, E., & Keegan, R. J. (2022). Sustaining optimal performance when the stakes could not be higher: Emotional awareness and resilience in emergency service personnel (with learnings for elite sport). *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.891585

Jakovljevic, M. (2023). Psychiatria Danubina for the better world and global mental health enlightenment 2.0. *Psychiatria Danubina*, *35*(1), 4-7. https://doi.org/10.24869/psyd.2023.4

Kent, S., Devonport, T. J., Lane, A. M., Nicholls, W., & Friesen, A. P. (2018). The Effects of Coping Interventions on Ability to Perform Under Pressure. *Journal of Sports Science & Medicine*, *17*(1), 40-55.

Kopilaš, V. (2019). Person-centered care and access to drugs in the digital environment: To cure or to sell. *Croatian Medical Journal*, *60*(2). https://doi.org/10.3325/cmj.2019.60.174

Krane, V. (1994). The Mental Readiness Form as a Measure of Competitive State Anxiety. *The Sport Psychologist*, *8*(2), 189-202. https://doi.org/10.1123/tsp.8.2.189

Kurtak, M., Gambiraža, M., Vrdoljak, M., Krajček Nikolić, K., Andrić, M., Valpovac, M., Kopilaš, V., Popović, S., & Ćosić, K. (2024). Startle Effect Analysis Based on Multimodal Physiological Features in a Fighter Aircraft Simulator. *International Conference on Cognitive Aircraft Systems*.

Le Glaz, A., Haralambous, Y., Kim-Dufor, D.-H., Lenca, P., Billot, R., Ryan, T. C., Marsh, J., DeVylder, J., Walter, M., Berrouiguet, S., & Lemey, C. (2021). Machine Learning and Natural Language Processing in Mental Health: Systematic Review. *Journal of Medical Internet Research*, *23*(5), e15708. https://doi.org/10.2196/15708

Maples-Keller, J. L., Bunnell, B. E., Kim, S.-J., & Rothbaum, B. O. (2017). The Use of Virtual Reality Technology in the Treatment of Anxiety and Other Psychiatric Disorders. *Harvard Review of Psychiatry*, *25*(3), 103-113. https://doi.org/10.1097/HRP.0000000000000138529

Maresca, G., Corallo, F., Catanese, G., Formica, C., & Lo Buono, V. (2022). Coping Strategies of Healthcare Professionals with Burnout Syndrome: A Systematic Review. *Medicina*, *58*(2), 327. https://doi.org/10.3390/medicina58020327

Marquardt, N., Hannig, C., & Hannig, S. (2018). The impact of mental readiness on driving performance and traffic safety. *International Journal of Safety and Security Engineering, 8* (1), 10-19. https://doi.org/10.2495/SAFE-V8-N1-10-19

McDonald, J., Orlick, T., & Letts, M. (1995). Mental Readiness in Surgeons and Its Links to Performance Excellence in Surgery. *Journal of Pediatric Orthopaedics*, *15*(5), 691-697. https://doi.org/10.1097/01241398-199509000-00027

McEwen, B. S. (2007). Physiology and Neurobiology of Stress and Adaptation: Central Role of the Brain. *Physiological Reviews*, *87*(3), 873-904. https://doi.org/10.1152/physrev.00041.2006

Morrison, J.E., & Fletcher J.D. (2002). Cognitive readiness. Alexandria, VA: Institute for Defense Analses.

Naegeli, C., Zeffiro, T., Piccirelli, M., Jaillard, A., Weilenmann, A., Hassanpour, K., Schick, M., Rufer, M., Orr, S. P., & Mueller-Pfeiffer, C. (2018). Locus Coeruleus Activity Mediates Hyperresponsiveness in Posttraumatic Stress Disorder. *Biological Psychiatry*, *83*(3), 254-262. https://doi.org/10.1016/j.biopsych.2017.08.021

Posada-Quintero, H. F., & Chon, K. H. (2020). Innovations in Electrodermal Activity Data Collection and Signal Processing: A Systematic Review. *Sensors*, *20*(2), 479. https://doi.org/10.3390/s20020479

Sabry, F., Eltaras, T., Labda, W., Alzoubi, K., & Malluhi, Q. (2022). Machine Learning for Healthcare Wearable Devices: The Big Picture. *Journal of Healthcare Engineering*, *2022*, 1-25. https://doi.org/10.1155/2022/4653923

Salzman, C. D., & Fusi, S. (2010). Emotion, Cognition, and Mental State Representation in Amygdala and Prefrontal Cortex. *Annual Review of Neuroscience*, *33*(1), 173-202. https://doi.org/10.1146/annurev.neuro.051508.135256

Sarker, I. H. (2021). Machine Learning: Algorithms, Real-World Applications and Research Directions. *SN Computer Science*, *2*(3), 160. https://doi.org/10.1007/s42979-021-00592-x

Sarmiento, L. F., Lopes da Cunha, P., Tabares, S., Tafet, G., & Gouveia Jr, A. (2024). Decision-making under stress: A psychological and neurobiological integrative model. *Brain, Behavior, & Immunity - Health*, *38*, 100766. https://doi.org/10.1016/j.bbih.2024.100766

Seitz, R. J. (2022). Believing and Beliefs—Neurophysiological Underpinnings. *Frontiers in Behavioral Neuroscience*, *16*. https://doi.org/10.3389/fnbeh.2022.880504

Souza-Talarico, J. N. de, Marin, M.-F., Sindi, S., & Lupien, S. J. (2011). Effects of stress hormones on the brain and cognition: Evidence from normal to pathological aging. *Dementia & Neuropsychologia*, *5*(1), 8-16. https://doi.org/10.1590/S1980-57642011DN05010003

Thakkar, A., Gupta, A., & De Sousa, A. (2024). Artificial intelligence in positive mental health: a narrative review. *Frontiers in Digital Health*, *6*. https://doi.org/10.3389/fdgth.2024.1280235Thompson, M. M., & McCreary, D. R. (2006). Enhancing Mental Readiness in Military Personnel. In A. B. Adler, C. A. Castro, & T. W. Britt (Eds.), *Military life: The psychology of serving in peace and combat: Operational stress* (pp. 54-79). Praeger Security International.

Thornton, M. A., & Tamir, D. I. (2024). Neural representations of situations and mental states are composed of sums of representations of the actions they afford. *Nature Communications*, *15*(1), 620. https://doi.org/10.1038/s41467-024-44870-7

vonRosenberg, J. (2019). Cognitive Appraisal and Stress Performance: The Threat/Challenge Matrix and Its Implications on Performance. *Air Medical Journal*, *38*(5), 331-333. https://doi.org/10.1016/j.amj.2019.05.010

Wiederhold, B. K. (2025). From Cyberspace to Outer Space: How Technology Will Preserve Mental Health in the Final Frontier. *Cyberpsychology, Behavior, and Social Networking*, *28*(1), 1-3. https://doi.org/10.1089/cyber.2024.0609

Correspondence:
Krešimir Ćosić
University of Zagreb Faculty of Electrical Engineering and Computing Unska 3, 10000 Zagreb, Croatia
kresimir.cosic@fer.hr