Strain in the Digital Era: Understanding Techno-Stress and Its Physiological Outcomes

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Abstract

In an era of rapid technological advancements, the impact of techno-stress on individuals has become a critical area of research. This study presents a conceptual analysis that synthesises existing literature on techno-stress dimensions (techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty) and links these dimensions to physiological outcomes. The research enhances the techno-stress literature by consolidating fragmented findings and redirecting attention from well-researched psychological outcomes to the less explored physiological ones. Additionally, the study suggests future research directions to validate the framework through empirical testing and the development of intervention strategies.

Keywords:

Physiological outcomes, techno-complexity, techno-insecurity, techno-invasion, techno-overload, techno-stress, techno-uncertainty.

1. INTRODUCTION

In the contemporary digital era, technology has become deeply embedded in daily life, fundamentally altering the way employees interact with their work and personal environments (Kraus et al., 2021). While technological advancements have markedly enhanced productivity and connectivity, they have simultaneously introduced novel stressors, collectively referred to as techno-stress (Tarafdar et al., 2024). Techno-stress encompasses various dimensions such as techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty (Nastjuk et al., 2023). These dimensions, also called techno-stressors, refer to the technology-induced demands that lead to strain responses, which can be psychological (such as anxiety, exhaustion, or burnout) or behavioural (absenteeism and turnover) (Nastjuk et al., 2023).

Despite extensive research on techno-stress, previous studies have predominantly emphasised psychological and behavioural responses, often overlooking the physiological effects associated with different techno-stress dimensions (Sonnentag & Fritz, 2014; Borle et al., 2021; Marsh et al., 2022). Understanding the impact of techno-stressors on employees' physiological well-being is imperative, as prolonged exposure to technology-induced stress has been linked to adverse health outcomes, including cardiovascular issues, hormonal imbalances, and emotional disturbances (Tams et al., 2020; Mishra & Rašticová, 2024). Furthermore, the meta-analysis by Nastjuk et al. (2023) highlighted that numerous studies have investigated the association of techno-stress with psychological and behavioural outcomes. However, the physiological impact of various techno-stress dimensions has not been thoroughly explored (Nastjuk et al., 2023). Addressing these gaps is crucial for a comprehensive understanding of techno-stress and its broader implications for health (Day et al., 2012; Galluch et al., 2015).

This research is a conceptual article that synthesises existing literature on techno-stress and strain outcomes. The study aims to bridge the research gaps by developing a conceptual framework that integrates techno-stress with physiological outcomes. Specifically, the paper investigated how techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty influence physiological markers, offering a foundation for future empirical validation. By providing an in-depth analysis of these relationships, the study seeks to advance theoretical knowledge of techno-stress as a multi-systemic phenomenon and offer practical insights into managing its physiological impacts (Tams et al., 2018). Furthermore, the research examined the effectiveness of various interventions and coping mechanisms designed to mitigate these effects.

The structure of this paper is as follows: The next section provides a comprehensive literature review of existing research on techno-stress, highlighting the dimensions of techno-stress and its physiological outcomes. This is followed by the development of a conceptual framework and a discussion of the methodology used to measure techno-stress in the existing literature. Thereafter, both theoretical and practical implications have been discussed. Furthermore, the next section proposes recommendations for addressing the study's limitations and exploring new avenues for research. Lastly, the study provides the conclusion.

2. LITERATURE REVIEW

2.1 Technostress

Technostress is a type of stress that individuals experience due to their inability to keep up with the rapid advancements and demands of Information and Communication Technologies (ICTs) (Tarafdar et al., 2007). Craig Brod introduced the term in 1984, describing it as a "modern disease of adaptation caused by an inability to cope with new technologies in a healthy manner" (Brod, 1984, p. 16). The concept was further revised by Weil and Rosen (1997), who describe technostress as an adverse impact technology has on people's attitudes, beliefs, behaviours, or psychology. Techno-stress is driven by various factors, known as techno-stress creators or stressors, which arise from the interaction between individuals and ICTs (Tarafdar et al., 2024). Based on the literature review, Tarafdar et al. (2007) and Ragu-Nathan et al. (2008) identified five critical dimensions of techno-stress, which include: techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty. (1) Techno-overload refers to situations where ICTs force users to work faster, more intensively, or longer (Thurik et al., 2023). (2) Techno-Invasion describes the pervasive nature of technology that blur the boundaries between work and personal life, leading to the encroachment of work into personal time and space and creating a sense of constant pressure (Tarafdar et al., 2007). (3) Techno-complexity refers to the complexity of ICTs that makes users feel inadequate or overwhelmed by their skills (Marsh et al., 2022). It forces users to invest significant time and effort in learning and mastering new technologies, which can lead to frustration and stress (Tarafdar et al., 2014). (4) Techno-insecurity is the fear of losing one's job or relevance due to rapid technological advancements or being replaced by more tech-savvy employees (Thunberg et al., 2023). This dimension highlights the anxiety associated with staying updated and competitive in a constantly evolving digital landscape

(Tarafdar et al., 2014). (5) Techno-uncertainty reflects the continuous changes, updates, and modifications in ICTs that create uncertainty for users. It requires them to continually learn and adapt, which can lead to feelings of instability and stress (Ragu-Nathan et al., 2008).

2.2. Physiological Outcomes

Techno-stress induces significant physiological responses, manifesting through various bodily reactions to technology-related stressors. These responses include cardiovascular, biochemical, and gastrointestinal symptoms, as evidenced by elevated cortisol levels, increased heart rate, and heightened skin conductance (Riedl et al., 2013; Weinert et al., 2020). The perception of technology as a stressor leads to both psychological and physiological reactions. Specifically, stressors such as system unreliability led to increased emotional sweating and elevated levels of stress hormones (Weinert et al., 2020). While physiological strain may occur subconsciously, its implications for long-term health are significant. Prolonged exposure to such stressors can lead to serious health issues, such as cardiovascular problems, underscoring the importance of addressing these physiological outcomes, as they often reflect immediate, involuntary responses driven by external stimuli rather than conscious cognitive evaluation (Riedl, 2013; Tams et al., 2014).

3. CONCEPTUAL FRAMEWORK: TECHNO-STRESS AND PHYSIOLOGICAL OUTCOMES

Based on the literature review, the study introduced a Conceptual Framework of Techno-Stress and Physiological Outcomes (see Figure 1), which extends the existing techno-stress framework by explicitly linking techno-stress dimensions to physiological outcomes. The model has been built upon the five techno-stress dimensions proposed by Tarafdar et al. (2007) and Ragu-Nathan et al. (2008) and incorporates physiological response mechanisms from stress research (Mishra & Rašticová, 2024; Riedl et al., 2012; Weinert et al., 2020). Prior studies have established relationships between techno-stress dimensions and various negative outcomes; however, these findings remain fragmented across disciplines (Nastjuk et al., 2023), underscoring the need for empirical research recommendations. Furthermore, the Conceptual Model is grounded in the

Person-Environment (P-E) Fit Theory (Edwards & Cooper, 1990), which posits that stress arises when there is a misalignment between an individual's abilities and the demands of their environment. In the context of techno-stress, this misfit occurs when employees struggle to adapt to rapid technological advancements, resulting in physiological strain. Figure 1 illustrates the pathways through which each dimension of techno-stress triggers specific physiological responses. A detailed explanation of each conceptual relationship has been discussed as follows:

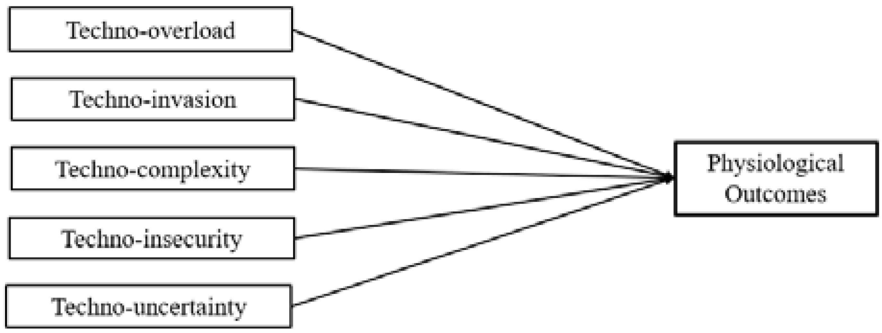

Figure 1: Conceptual Framework
Source: Author's Own

3.1. Techno-Overload and Physiological Outcomes

Techno-overload arises when employees are overwhelmed by the sheer volume of technology-related tasks, leading to excessive cognitive processing and mental fatigue (Thurik et al., 2023). This cognitive overload triggers the body's stress-response systems, leading to physiological responses such as elevated cortisol levels, increased heart rate, and increased skin conductance (Riedl, 2013). Elevated cortisol, a key stress hormone, is commonly associated with increased arousal and prolonged activation of the hypothalamic-pituitary-adrenal axis, contributing to chronic stress if the overload persists (Riedl et al., 2012; Sonnentag & Fritz, 2014; Mishra & Rašticová, 2024). Muscle tension is another common symptom, often manifesting in the neck, back, and shoulders, as employees constantly work with technology (Riedl, 2013). Chronic activation of these physiological markers may lead to immune system suppression, increased fatigue, and long-term health risks such as hypertension and cardiovascular disease (Riedl et al., 2012; Ayyagari et al., 2011).

3.2. Techno-Invasion and Physiological Outcomes

Techno-invasion refers to the constant intrusion of technology into personal and professional lives, eroding boundaries between work and leisure (Tarafdar et al., 2014). This continuous connectivity disrupts regular routines and extends exposure to stress. Consequently, physiological outcomes such as sweating, gastrointestinal disturbances, and elevated blood pressure emerge from the persistent pressure to respond to technology-driven demands (Riedl, 2013; Mishra & Rašticová, 2024). Over time, these sustained physiological responses can lead to more serious health problems, such as cardiovascular issues, including hypertension and increased risk of heart disease (Riedl et al., 2012; Riedl et al., 2013).

3.3. Techno-Complexity and Physiological Outcomes

Techno-complexity involves the cognitive challenge of understanding or using intricate technological systems, which places significant mental demands on employees (Borle et al., 2021). The complexity of these systems often results in frustration, confusion, and mental fatigue, triggering the activation of physiological stress responses. As users struggle to navigate complicated technologies, the body responds by releasing stress hormones like cortisol and adrenaline (Riedl, 2013). Elevated cortisol levels are a marker of the activation of the hypothalamic-pituitary-adrenal (HPA) axis, a key system involved in the body's stress response, while adrenaline triggers immediate physiological changes, including increased heart rate and blood pressure (Riedl et al., 2012). Furthermore, techno-complexity has been linked to increased skin conductance, a physiological indicator of sympathetic nervous system activation (Mishra & Rašticová, 2024). These physiological markers not only indicate immediate stress but, if the complexity persists over time, may lead to chronic stress-related health issues, such as cardiovascular diseases and impaired cognitive functioning (Weinert et al., 2020).

3.4. Techno-Insecurity and Physiological Outcomes

Techno-insecurity arises from fears of being displaced by technological advancements or becoming irrelevant in the workforce, which can significantly heighten stress levels (Fischer & Riedl, 2017). This fear often triggers physiological stress responses, such as increased heart rate, muscle tension, and elevated blood pressure, as employees grapple with anxiety over their professional futures (Schellhammer et al., 2013). Research suggests that these physiological responses are primarily driven by the activation of the body's fight-or-flight system, particularly the sympathetic nervous system, leading to an increase in adrenaline and cortisol (Riedl, 2013; Adam et al., 2016). Over time, prolonged exposure to techno-insecurity can contribute to chronic health conditions such as hypertension, elevated blood pressure, and stress hormones, which place a strain on the cardiovascular system (Sonnentag & Fritz, 2015).

3.5. Techno-Uncertainty and Physiological Outcomes

Techno-uncertainty refers to the continuous and unpredictable changes in technology, creating uncertainty about the future and leading to difficulties in adapting to new systems or software (Marsh et al., 2022). Techno-uncertainty results in significant psychological and physiological outcomes as employees struggle to meet ever-evolving technological demands (Borle et al., 2021). Physiologically, techno-uncertainty triggers stress responses, such as elevated cortisol levels, increased heart rate, and heightened blood pressure, reflecting the body's reaction to perceived instability and the constant need to adapt (Riedl, 2013; Peters et al., 2017). The uncertainty about effectively using or managing new technologies also leads to increased cognitive load, resulting in mental fatigue, which further activates the body's stress-response systems (Ayyagari et al., 2011). Prolonged exposure to techno-uncertainty can lead to chronic physiological issues such as headaches, muscle tension, and gastrointestinal problems, as the stress experienced in response to constant technological change strains the nervous and musculoskeletal systems.

4. METHODS OF ASSESSING TECHNOSTRESS

Previous research on techno-stress employed two methods for measuring the degree of stress experienced by participants. First is the questionnaire (psychometric method), and second is the biomarker method (Mishra & Rasticova, 2024). Both methods offer distinct strengths and weaknesses, making them complementary in understanding the multifaceted nature of techno-stress (Tams et al., 2014).

Questionnaires are widely used for assessing technostress, particularly in capturing subjective experiences. Questionnaires collect information from the participants about how they felt in stressful situations. They rely on self-reporting and allow researchers to measure specific dimensions of technostress, such as techno-overload, techno-invasion, techno-complexity, techno-uncertainty or techno-insecurity (Tarafdar et al., 2007). One of the primary advantages of questionnaires is their ease of administration; they are more cost-effective to implement on a large scale and are relatively straightforward to analyse. Moreover, these instruments allow individuals to reflect on their emotional and psychological responses to technology, providing detailed insights into their personal coping mechanisms and perceived stress. However, questionnaires are inherently subjective, which can introduce biases such as social desirability or memory recall issues. Participants may underreport or overreport their stress levels based on personal factors that do not reflect their true physiological state (Mishra & Rašticová, 2024). Moreover, while questionnaires provide valuable information on the psychological impacts of technostress, they do not capture the body's biological response, which can limit the understanding of how stress affects physical health.

On the other hand, biomarkers offer an objective measure of the physiological effects of technostress by assessing changes in biological systems (Riedl et al., 2012; Riedl, 2013). Biomarkers such as cortisol levels, heart rate variability, blood pressure, and skin conductance provide direct evidence of the body’s stress response (Mishra & Rašticová, 2024). Cortisol, for instance, is a well-known marker of stress hormone in humans, and elevated levels have a detrimental effect on health (Riedl et al., 2012). By measuring these physiological outcomes, researchers can gain insight into the impact of technostress on the autonomic nervous system, revealing how it affects cardiovascular health, immune function, and overall well-being (Riedl, 2013; Riedl et al., 2013). Unlike questionnaires, biomarkers are free from subjective reporting biases and provide real-time, quantifiable data on how the body responds to stress. However, collecting biomarkers is often more complex, requiring specialised equipment and expertise, which can increase costs and limit the size of study samples.

In comparing the two, it becomes clear that questionnaires and biomarkers assess different facets of technostress. Questionnaires are well-suited for measuring the perceived psychological effects of technology use, allowing employees to express how they feel about the impact of technology on their work and life, for example, the techno-stress questionnaire developed by Tarafdar et al. (2007). Biomarkers, in contrast, provide a physiological lens, demonstrating how the body responds to technology demands at a biological level (Tams et al., 2014). The choice between questionnaires and biomarkers depends on the research goals. If the objective is to understand the psychological perceptions of technostress and how individuals feel about their interaction with technology, questionnaires are an appropriate tool (e.g., Ayyagari et al., 2011). However, if the research aims to explore how technostress impacts physical health or to measure chronic stress responses, biomarkers offer a more precise and objective method (e.g., Riedl et al., 2013; Tams et al., 2018). In practice, some studies combine both methods to obtain a more comprehensive picture of technostress, integrating subjective experiences with physiological data to better understand how techno-stress affects both the mind and body (Wineart et al., 2020). Using both approaches, researchers can develop a more nuanced and holistic understanding of the complex relationship between technostress and overall well-being (Tams et al., 2014). Furthermore, the previous literature also lacks a well-established psychometric scale for measuring the physiological outcomes of techno-stress.

5. IMPLICATIONS

5.1. Theoretical Implications

The study highlights several important directions for future research. There is a need to further explore the physiological mechanisms underlying techno-stress. Future studies should focus on linking distinct dimensions of techno-stress, such as techno-overload, techno-invasion, techno-uncertainty, techno-insecurity, and techno-complexity, to physiological outcomes such as heart rate, blood pressure, skin conductance, and cortisol levels. The current research broadens the scope beyond traditional psychological responses and offers a more comprehensive understanding of how both conscious and unconscious physiological outcomes affect overall well-being. Furthermore, there is potential to create advanced dual-level models of techno-stress that encompass both psychological and physiological outcomes, recognising that they may not always be in harmony. This approach would involve considering situational factors, such as the specific type of technology being used or the context of its use, which have the ability to influence the intensity of physiological stress responses. Additionally, future research could broaden the theoretical framework to include other dimensions such as techno-addiction, techno-unreliability and techno-anxiety, offering deeper insights into the prolonged effects of technology use on mental health and well-being. The current study also warrants the development and empirical validation of the physiological outcome scale. Such an effort would help to bridge the gap between techno-stress and physiological outcomes. Lastly, examining individual resilience and coping mechanisms, such as emotional intelligence and psychological flexibility, could offer a better understanding of why some employees are more physiologically resilient to techno-stress than others.

5.2. Practical Implications

The research suggests innovative strategies for managing the physiological impacts of techno-stress. One promising avenue is the use of biofeedback and wearable technologies that enable employees to monitor real-time physiological stress indicators such as cortisol levels, heart rate, and blood pressure. The reliance on self-reported data for psychological and behavioural outcomes may introduce subjective bias and social desirability effects. To enhance the robustness of future findings, incorporating objective measures, such as wearable devices that track real-time physiological responses, is recommended to reduce the subjectivity associated with stress assessment. These interventions could play a crucial role in mitigating the long-term effects of chronic stress in the workplace.

Additionally, the study highlights the importance of adaptive technology design, where user interfaces are personalised to adjust complexity or reduce task overload based on physiological feedback. Such adaptive systems could significantly improve user comfort and reduce stress, particularly for employees dealing with techno-overload or techno-complexity.

Furthermore, Organizational policies should go beyond basic digital detox strategies to include structured physiological recovery periods where employees engage in activities such as mindfulness, relaxation techniques, or physical exercise. Public health initiatives should also emphasise education about the physiological effects of techno-stress, promoting healthier technology use habits across the population. Longitudinal studies are also needed to investigate the long-term health impacts of techno-stress, particularly concerning chronic conditions such as cardiovascular disease and mental health issues. These practical interventions and future research directions are essential for addressing the broader implications of techno-stress on both employee well-being and organisational and societal health outcomes.

6. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Despite the valuable insights provided by this study, several limitations must be acknowledged. First, while the study effectively highlights the physiological outcomes of techno-stress, it does not extensively address the long-term effects of these physiological changes on overall health and well-being. To address this gap, future research should consider longitudinal studies that examine the cumulative impact of sustained techno-stress on chronic health conditions such as cardiovascular disease, metabolic disorders, and mental health challenges. Second, the study may not capture the complete sets of stressors in varied technological environments due to its concentration on specific techno-stress dimensions: techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty. Future research should explore additional stressors and investigate their contributions to physiological outcomes. Third, the study does not fully account for individual differences in stress resilience or coping mechanisms. Future research should examine how personal traits, such as emotional intelligence, cognitive flexibility, or psychological capital, moderate the relationship between techno-stress and physiological outcomes. Investigating these personal factors may help explain why some employees experience more severe physiological outcomes from techno-stress while others demonstrate greater resilience. Fourth, although the study proposes interventions like biofeedback-based stress management and adaptive technology design, it does not evaluate the effectiveness of these solutions in real-world settings.

Future research should assess the practical implementation of such technologies and policies and conduct experimental or field studies that track stress levels and health outcomes before and after implementing these interventions. Finally, future research should replicate this research by empirically testing the relationship between techno-stress dimensions and physiological outcomes using validated psychometric scales.

7. CONCLUSION

The usage of computers, the internet, smartphones, and other technologies has greatly benefited users, organisations, and society. However, using technology can also lead to noticeable stress perceptions, a condition known as technostress, which can harm users' health (Riedl et al., 2013). The study explores that techno-stress dimensions increased physiological arousal and strain, which must not be ignored in techno-stress research. The present study is an essential step towards a better understanding of techno-stress dimensions in stress perceptions. Comprehensive research is necessary to reduce the detrimental impacts of techno-stressors on health outcomes. We draw the conclusion that by concentrating on the conscious part (i.e., psychological or self-reported outcomes) "tip of the iceberg," the research on technostress has missed a significant portion of techno-stress research. Thus, testing the unconscious part of technostress (physiological outcomes) is a perfect way to start researching the underwater portion of that "iceberg." In order to completely comprehend the effects of technology on people, it may eventually be necessary to use both measures and combine the insights they bring to produce a more comprehensive picture of the psychological and physiological outcomes of technology.

Conflict of Interest

The authors declare no conflicts of interest relevant to this article.

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