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REVIEW

Role and Status of Biomarkers in Technostress Research: A Systematic Review

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Abstract: The revolution in technology has impacted the work and personal lives of human beings greatly. While it has introduced the mankind to a more comfortable life, it has brought in the stress too in the form of technostress, the situation where a person fails to cope up with the ever-advancing technology and experiences stress symptoms. The increasing intensity of technostress calls for more research on technostress diving deeper into the causes and coping mechanisms. However, technostress research requires successful and reliable assessment of stress. It has been observed in recent years that biomarkers such as cortisol and salivary alpha amylase are reliable indicators of stress. There are several reports where the researchers have used questionnaires and surveys to assess the technostress, but the number of studies using biomarkers for technostress assessment is limited. It has been established that biomarker assessment is an important complement to the surveys to study the technostress. Here, we summarize the important studies done on technostress using the biomarkers along with the rationale of using these biomarkers.

Keywords: technostress, biomarkers, cortisol, skin conductance, salivary alpha amylase, heart rate variability

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Introduction

Advancement in information and communication technology (ICT) has introduced us to many new advantages, such as greater flexibility, ease of work from home, better access to information, easier communication, etc. However, it has negative impacts too in terms of stress and impaired mental health.[1] Depression, illegal behaviour, misuse, and addiction are a few other negative outcomes reported due to ICT-related interruptions, overload, and overuse.[2]

Initially, Craig Brod gave the term ‘technostress’ for the human beings’ psychological state or stress that resulted from their interaction with machines and technology. To be specific, Brod defined technostress as ‘a modern disease of adaptation caused by an inability to cope with the new computer technologies in a healthy manner,’ in his book ‘Technostress: The Human Cost of the Computer Revolution’.[3] Later, as the technology improved and kept invading more and more into the daily lives of humans, the term ‘technostress’ was redefined to include any direct or indirect negative impact of technology on a person’s behaviour, attitude, or body physiology.[4]

Ragu-Nathan et al[5] gave three different factors that induce technostress. The first factor is the high dependency on technology in the workplace. The second factor is the knowledge gap between workers and advanced technology. As the ICTs keep getting updated, the workers always feel the need to learn and cope with the more and more sophisticated technology. And the third factor is the change in working environment and culture due to the use of technology. ICT has increased the scope of remote supervision and expectation of multitasking.

On the other hand, Tarafdar et al[6] have identified five causative factors of technostress, namely, Techno-overload (workers being forced to work faster and longer), Techno-invasion (users can be reached anytime, causing imbalance between work and personal front); Techno-complexity (users feel insufficiently skilled and are forced to spend more time and effort in learning new aspects of technology); Techno-insecurity (users feel concerned about being replaced by new technology or other people who know the technology better); and Techno-uncertainty (users feel unsettled and uncertain due to continuous changes and upgrades in technology, forcing them to constantly educate themselves).

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The consequences of technostress may be detrimental, ranging from poor performance at work to deterioration of health. Llorens et al[7] have divided the negative outcomes of technostress into four categories: physiological, psychosocial, organizational, and societal consequences. Physiological consequences include psychosomatic problems such as sleep disturbance, headache, fatigue, weakening of immune system, muscle pain, depression, increased adrenaline and noradrenaline, increased blood pressure and heart rate, and elevated skin conductance. Psychological consequences of technostress may include anxiety, job dissatisfaction, mental exhaustion (burnout), etc. Organizational consequences of technostress can be absenteeism, decreased commitment, and low performance. Lastly, societal impact of technostress may negatively affect the user's socializing activities, resulting in decreased social circle due to mood swings and increased irritability.[8]

Thus, ICT has acquired an important place in humans' lives, bringing many advantages, but just as many negative consequences too. These harmful consequences of technostress indicate the need for and importance of assessment and research on technostress, its causes, and its solutions. The present review report therefore aims to present an overview and role of biomarkers as stress indicators, and their status in technostress research.

Questionnaire Vs Biomarkers for the Assessment of Technostress

Research and experiments on technostress currently employ one or both of two methodologies: first is questionnaires (psychometric method), and second is simulation of stressful events and measuring the degree of stress experienced by the participants (NeuroIS method). Questionnaires are a collection of questions that collect information from the participants about how they felt in stressful situations. The questionnaire may also include questions about their performance or approach during stressful situations. The questions may be about real-life situations or a simulated situation.[9,10] However, this method has its limitations. It depends on the person's recall of the situation and his feelings. The participant may be unable to clearly recall his stress level during the task. The response also depends on the personality of the participants; one participant may be more motivated and might not accept he felt stress, while the other may even over-estimate the stress he experienced.[11,12]

NeuroIS methods utilize the body's physiological reactions towards stress. When the brain experiences stress, stress centers in the brain get activated. The stress systems then prepare the whole body to handle the stress.[13] The Sympathetic Nervous System (SNS) gets activated which results in release of epinephrine and norepinephrine from the adrenal medulla, which in turn causes an increase in heart rate and blood pressure. Along with the up-regulation of SNS, down-regulation of the Parasympathetic Nervous System (PNS) also occurs.[14] The hypothalamic–pituitary adrenal (HPA) axis releases the stress hormone cortisol from the adrenal cortex to modify the effects of SNS and PNS.[15] The consequences can be dangerous when a person is exposed to stress for longer duration (chronic stress), or when the person's physiological responses fail to cope with the stressful situation.[16,17] Under stress, SNS, PNS, and HPA axis interact with inflammatory system (eg, glucocorticoids), which is involved in mediating the negative effects of stress on health.[18] Exposure to acute stress may result in systemic low-grade inflammation, which may further lead to the development of various diseases like cardiovascular diseases, type-2 diabetes, cancer, skin aging, urticaria, asthma, or obesity.[19]

Few studies indicated that NeuroIS method is just an alternative to psychometric method and both methods help explore the same dimensions of the technostress. To clarify this, Tams et al[20] investigated the correlation between a psychological and a physiological method to measure technostress in relation to performance in a computer-based task. Their results showed that the measurement of stress using salivary alpha-amylase (sAA) measurement as physiological method explained and predicted variance in performance in the computer-based task over and above the prediction obtained by the self-reported stress measurement. They thus concluded that NeuroIS is an important complement and not just an alternative to psychometric method in technostress research. The physiological and psychological methods of technostress measurement may not be interchangeable. Instead, when combined, the researchers may achieve higher levels of explained variance in the technostress measurement than either method could do it alone (A case holistic representation using divergent measures). Gruttola1 et al (2019) too have emphasized on the importance of brain processes to reveal consumers' experiences that cannot be known through self-reported data and questionnaires.

Riedl has concluded in his review report[21] that stress hormones start acting inside the body and causing damage to the health even before the person starts realizing and experiencing the negative effects of stress (example, fatigue, palpitation, etc.) and is able to report them in questionnaires. Thus, self-reports should be complemented by investigation of biological markers in technostress research to make the stress measurement more reliable.

Methodology

This review includes the studies published after the year 2000 till the year 2023. The databases searched are PubMed and Google Scholar. The initial keywords included to perform the search were as follows: (i) Physiological methods of measuring technostress, (ii) biological methods of measuring technostress, and (iii) biomarkers for technostress assessment. The search yielded 3500 (Google Scholar) and 133 (PubMed) results for keyword (i), 3060 (Google Scholar) and 71 (PubMed) results for keyword (ii), and 268 (Google Scholar) and 23 (PubMed) results for keyword (iii). The criterion for selecting the papers to be considered was finding relevance either through the title or the text that appeared in the search databases. The relevance criterion was use of any biological method to measure technostress. Based on this, 154 papers were shortlisted. After studying these papers, a list of biomarkers most used for technostress assessment was established.

Next phase included searching for the results that mentioned these particular biomarkers being used for technostress assessment. So, the next search keywords were "skin conductance used in technostress" that yielded 324 results in total; "cortisol used in technostress" that yielded 982 results in total; "salivary alpha amylase used in technostress" that yielded 119 results in total; 'C-reactive protein used in technostress that yielded 49 results in total; "heart rate used in technostress assessment" that yielded 3645 results in total; and "blood pressure used in technostress" that yielded 1634 results in total. Though the number of results generated in the databases was huge, only few were found to be relevant research studies. To be precise, 2 studies were found to be relevant for skin conductance used for technostress assessment. This number for cortisol, salivary α-amylase, C-reactive protein, heart rate and blood pressure was 3, 5, 2, 3, and 2, respectively. These studies are included in this review.

Status of Biomarkers in Technostress Research

As discussed above, there are mainly two methods of measuring technostress, ie questionnaires and measurement of biomarkers. Questionnaires give compromised results, making the biomarkers more suitable to measure the actual experience of the stress bearers. The following sections present the state of the art of biomarkers used as indicators of stress level.

Table 1 summarizes the use of biomarkers in technostress research.

Table 1 Status of Biomarkers in Technostress Research

S. No.	Biomarker	Objective/Stressor	Sample Size	Conclusion	Reference
1.	Skin Conductance	To assess role of gender in technostress	N = 77	Males are more sensitive than females to technostress and users' gender must also be considered in technostress research.	[22]
2.	Skin Conductance	To study effect of instrumental and emotional support on user's performance, techno-exhaustion, and physiological arousal	N = 73	Instrumental support directly affected the performance, techno-exhaustion, and physiological arousal, while emotional support only altered techno-exhaustion. Men respond better to instrumental support, and users with high computer self-efficacy might suffer worse technostress.	[23]

(*Continued*)

Table 1 (Continued).

S. No.	Biomarker	Objective/Stressor	Sample Size	Conclusion	Reference
3.	Cortisol	To analyze technostress associated with the remote virtual work environment during covid times	N = 142 (Egyptian university academic staff members from Menoufia University)	Level of technostress was significantly proportional to age, higher professions, female gender, and a bad workplace environment (poor WiFi). Cortisol level was significantly higher with overload and complexity of technostress.	[24]
4.	Cortisol	To study technostress creators and outcomes associated with remote working environment during COVID-19 pandemic	N = 273 (151 staff members and 122 students from five randomly selected medical and nursing schools)	The Egyptian medical staff members and students had moderate to high level of technostress which was associated with high burnout, strain, and cortisol level.	[25]
5.	Cortisol	To study the effects of system breakdown on changes in users' cortisol levels	N = 20 (males)	Cortisol level was significantly increased in the group exposed to the stressor, while it remained constant in the control group participants who were not exposed to the stressor.	[26]
6.	sAA	To examine two potential stressors, quantity and content of ICT-enabled interruptions	N = 23 and 180	ICT-enabled demands served as stressors and led to stress. ICT-enabled timing control negatively moderated the relationships between stressors and stress; method control negatively moderated the relationship perceptual conflict had with strain, while increasing perceptual overload's relationship to strain; and resource control negatively moderated perceptual overload's relationship with strain, while increasing perceptual conflict relationship with strain.	[27]
7.	sAA	To study how personality influences technostress and how perceptions of stress and objective strain differ from each other	N = 134	Stress and strain are not correlated, but they are inversely related to performance. An internal locus of control had a positive influence on objective strain.	[28]
8.	sAA	To compare the role of NeuroIS method and psychometric method in technostress research	Not found	Biomarkers method is an important complement and not just an alternative to psychometric method in technostress research.	[29]

(*Continued*)

Table 1 (Continued).

S. No.	Biomarker	Objective/Stressor	Sample Size	Conclusion	Reference
9.	CRP	To study technostressors: techno- and information overload, techno-complexity, techno-uncertainty, techno-insecurity, interruptions and multitasking	N = 173 (university hospital employees)	Technostress in the form of techno- and information overload is associated with burnout symptoms. The association remained significant when work overload was included in the multivariate model.	[30]
10.	Heart Rate Variability and Skin Conductance	To study influence of technostress and financial stress on users' digital financial decision-making responses	N = 15	Influence of unexpected technology behaviours is much more than perceived financial loss on: physiological arousal and emotional valence; feedback processing and decision-making	[31]
11.	Blood pressure and Heart Rate	To measure the stress experienced after receiving notification of deadline time and error messages during an assigned online task	N = 37	Performance of the users depends on the technostress that they experience. The users fail to advance their performance in situations where they face pressure, work overload and deadlines.	[32]
12.	Heart Rate and Skin Conductance	To study effect of system response time during human-computer interaction	N = 26	Heart rate and electrodermal activity were increased with the increase in system response time and did not depend on the expertise of the participants.	[33]
13.	sAA, Cortisol, Heart Rate Variability, CRP, secretory Immunoglobulin-A (s-IgA)	To analyze the biological stress responses to multitasking and work interruptions	N = 192	Dual- and multitasking as well as work interruptions trigger specific biological stress responses of SNS.	[34]
14.	Heart Rate Variability	To showcase how the preprocessing of captured data can influence the results and their interpretation, when compared to self-report data	N = 15 (employees of a publishing company)	A renewed call for deliberately making methodological decisions (such as those related to preprocessing of physiological data) and presenting methodological details in NeuroIS papers.	[35]
15.	Heart Rate and Blood Pressure	To study the effect of physical and mental workload, and Rest	N = 12 (females with no prior experience of laboratory experiments)	Heart Rate Variability is a more sensitive and selective marker for mental stress, because heart rate related variables reflect a central pathway in cardiovascular control mechanisms, whereas blood pressure is more likely to be influenced by local conditions in the working muscles, partially masking the effect of changes in mental workloads.	[36]

Skin Conductance

Skin conductance is also referred to as electrodermal activity (EDA). It can be used as a biomarker for stress because it is a reliable indicator of activity in the sympathetic division of autonomic nervous system (ANS).[37] ANS is that part of the human nervous system which becomes active after receiving signals of arousal and stress.[38] Thus, skin conductance is an established biomarker for stress and has been used in technostress research.

There are mainly two methods to record EDA: Endosomatic method and Exosomatic method. In endosomatic method, there is no external current used, while in exosomatic method, an external low electric current is used. Exosomatic method can measure skin resistance and skin conductance. Thus, recording of skin conductance involves placement of two small electrodes in contact with the skin and passing a low electrical current across the two electrodes. These two electrodes measure the change in the skin, if any, in response to a stressor. Measurement of skin conductance is based on Ohm's law, according to which, the skin conductance can be determined by measuring the current flowing across the electrodes while keeping the voltage constant.[38,39]

The skin conductance measurement has two components: tonic component and phasic component. The tonic component represents the absolute level of conductance and is referred to as skin conductance level (SCL). When there is an increase in skin conductance due to any external or internal stimuli, it constitutes the phasic component of skin conductance.[40]

Riedl et al[41] used skin conductance as stress indicator in their research to investigate the role of gender in technostress. They studied users' physiological reaction to the malfunctioning of computer. Their study was based on the theory that men undergo more "achievement stress" than women. To all the participants (of both the genders), two electrodes were attached to the index and middle fingers of the nondominant hand. After the electrodes were successfully attached and the system was working properly, the participants were given a task related to online shopping. The participants were then exposed to an unexpected system malfunction, and the difference in EDA (measured in microsiemens (µS)) was determined. The results revealed that skin conductance in case of men sharply increased after encountering computer malfunction in a time-pressured environment, hence men displaying significantly more stress than women in case of system breakdown when they had to finish the specific task under time pressure. The researchers thus concluded that males are more sensitive than females to technostress and suggested that users' gender must also be considered in technostress research.

Another experiment used skin conductance measurements in addition to subjective (questionnaires) and objective (task performance) measurements to investigate the effect of instrumental and emotional support on user's performance, techno-exhaustion, and physiological arousal. This study was based on the observation that technostress leads to poor end-user performance, increased techno-exhaustion, and physiological arousal. In this research, skin conductance was measured as an indicator of physiological arousal. The researchers used exosomatic skin conductance method that involves applying direct current to the skin. Two electrodes were installed to the non-dominant hand of the participants, and low-level voltage between the electrodes was measured. The skin conductance readings were taken once per second using a MentalBioScreen K3 device, which recorded conductance in microsiemens (µS). As per the results of this experiment, instrumental support directly affected the performance, techno-exhaustion, and physiological arousal, while emotional support only altered techno-exhaustion. The experiment also indicated that men respond better to instrumental support, and users with high computer self-efficacy might suffer worse forms of technostress.[23]

Cortisol

The hypothalamic–pituitary–adrenal (HPA) axis is a central regulatory system in human beings that is associated with the reaction to stressors.[42] Cortisol is one of the two main products of the HPA axis (dehydroepiandrosterone (DHEA) being the other).[43] Concentration of cortisol is the highest in the morning, and then declines throughout the afternoon and evening.[44] Psychological stress activates the HPA axis and causes an increase in the secretion of salivary cortisol.[45] Change in cortisol level is a well-established physiological reaction to stress and has been successfully used in technostress research. Changes in the cortisol level in saliva can be measured using a cheek swab. This data may help in experiments to determine the level of stress experienced by the participants.[46]

A study was conducted at Menoufia University, Egypt, to assess the technostress associated with the remote virtual work environment during covid times. Cortisol blood level of venous blood samples of participants was measured as a determinant of technostress, using Cobas e411 immunoassay analyzer (Roche Diagnostics, Mannheim, Germany). Technostress was found to be evident among the university staff members. Results revealed that level of technostress was significantly proportional to age, higher professions, female gender, and a bad workplace environment (poor WiFi). Cortisol level was found to be significantly higher with overload and complexity of technostress.[24]

Another study also investigated the technostress creators and outcomes associated with remote working environment during COVID-19 pandemic. This study was conducted in medicine and nursing colleges of 5 Egyptian universities and included both staff members and students. The technostress levels were determined through a questionnaire, along with participants' blood cortisol levels measured using an electrophoretic immunoassay in a Cobas e601 automatic analyzer (Roche Diagnostics, Mannheim, Germany). According to results, the Egyptian medical staff members and students had moderate-to-high level of technostress (33.3% of the staff members and 7.6% of students reported high technostress) which was found to be associated with high burnout, strain, and cortisol level.[25]

Riedl et al[46] conducted another study where the chosen stressor was computer crash in form of an error message. There were 2 groups, a control group and a treatment group. The first saliva sample was taken before the start of the experiment to determine the baseline cortisol level of the participants. Then, the participants were told that the usability of a website was being tested, and they had to add certain products in the shopping cart. The error message appeared exactly after 2.5 minutes on the screens of treatment group. The experiment was then stopped. The second sample of saliva was taken afterwards. It was found that the cortisol level was significantly increased in the treatment group, while it remained constant in the control group participants who were not exposed to the stressor.

Salivary α-Amylase

Salivary α-amylase (sAA), a glycosyl hydrolase of family 13, is another biomarker that is used in technostress research. It is a marker of the SNS and reveals the changes in adrenaline which is a stress hormone and directly indicates stress. sAA reaches the peak much faster as compared to cortisol (usually within 5 minutes) and thus is a better and more convenient marker for technostress experiments.[47] According to the literature, adrenaline hormone is more relevant in the context of tasks related to computers, thus making sAA more appropriate for technostress research.[48] In addition to physical stressors, sAA reacts to psychological stressors also, thus making it further useful for research on technostress. Also, since sAA samples (and cortisol samples too) can be withdrawn noninvasively from the participants, the sample collection process does not add to the stress and thus does not alter the results.[20] Moreover, what makes the analysis of sAA furthermore feasible is the fact that its amount in the saliva can be easily assessed by transferring the samples in frozen state to the assay laboratories, thus making the experiments possible even for those researchers who do not have direct access to an assay lab. Hence, many experiments have explored sAA as stress indicator in technostress experiments.[49]

Tams[50] studied the relationships among technological stressors, stress, performance, and related cognitive concepts. To evaluate his hypothesis, he performed an experiment where he integrated a memory task with the collection of sAA along with other measures, and he found that sAA was predicted by stress-related psychological concepts and thus predicted performance in the memory task. Hence, he could conclude that sAA is a practical alternative for technostress research experiments that require short-interval or repeated measurement points and simplified logistics.

In a recent study, Becker et al[34] investigated the biological stress responses to multitasking and work interruptions using sAA as biomarker. sAA was particularly chosen for the fact that sAA reflects changes in sympathetic nervous system (SNS) and researchers intended to study the changes in SNS specifically. Saliva samples were collected using *Salivettes* (Sarstedt, Nümbrecht, Germany) at six time points (various situations of multitasking and interruptions) to measure sAA. It was found that sAA levels (implies SNS reactivity) consistently and significantly increased during and decreased after the task in the situations of work interruptions, parallel dual-tasking, and multitasking, while there was no change during the control situation and single tasking.

Galluch et al[27] examined two potential stressors, quantity and content of ICT-enabled interruptions. Their experiment was based on the hypothesis that these stressors influence perceptual stress, which then manifests into physical strain. To test this hypothesis, they used sAA as a measure of strain. They examined three forms of control that may facilitate demand's influence on the stress process: timing control, method control, and resource control. Timing control serves as primary control that is present initially in an environment, while method control and resource control serve as coping behaviors that individuals adopt after they feel stressed. Results revealed that ICT-enabled demands served as stressors and led to stress. Results also indicated that ICT-enabled timing control negatively moderated the relationships between stressors and stress; method control negatively moderated the relationship perceptual conflict had with strain while increasing perceptual overload's relationship to strain; and resource control negatively moderated perceptual overload's relationship with strain while increasing perceptual conflict relationship with strain.

In another investigation, the researchers used sAA as the biomarker in their study about how personality influences technostress and how perceptions of stress and objective strain differ from each other. They examined three personality characteristics: locus of control, self-efficacy, and negative and positive affect. They studied how these personality traits relate with perceived stress, objective strain, and perceived performance. It was found that stress and strain are not correlated, but they are inversely related to performance. It was also observed that an internal locus of control had a positive influence on objective strain and that negative affects tend to feel more stress and have less confidence in their technical skills.[28]

To compare the role of NeuroIS method and psychometric method in technostress research, Tam et al[29] used sAA measurement as physiological method of technostress determination. The task given to the participants was a memory/concentration game. In middle of the task, instant messages were made to appear on the computer screen to induce stress. The messages were related to the task so that the participants pay attention. The messages were sent at two frequencies: control group received messages in low frequency, while experimental group received in high frequency. The stress was assessed by measuring sAA before and after the task. As mentioned earlier, they could conclude that biomarkers method is an important complement and not just an alternative to psychometric method in technostress research.

C Reactive Protein

As stated earlier, chronic low-grade inflammation is the central pathway through which stress may lead to the development of chronic diseases. It is usually evaluated by assessing the concentration of C-reactive protein (CRP) or of cytokines (eg, interleukins). CRP is a protein that is synthesized by the liver. The production of CRP increases when there is inflammation in the body. The level of CRP increases and decreases rapidly with the exposure or removal of the cause of the inflammation. The level of CRP remains constantly elevated in case of chronic inflammation such as chronic infections. CRP may also increase in case of trauma. Its moderate rise is often associated with a broad range of etiologies, for example, sleep disturbances, periodontal disease, etc.[51]

In an experiment, the stress induced by multitasking and work interruptions has been investigated. The participants were put in six different situations (one single task, three double tasks, one multitasks, and one control). The experimenters assessed heart rate and sAA as markers for SNS. They also measured heart rate variability as an indicator of PNS activity, and cortisol as an indicator of HPA axis activity. These parameters were analyzed throughout the experiment, while inflammatory markers, CRP and secretory immunoglobulin-A (s-IgA) were assessed before and after the task as well as 24 hours after it. The measures of all these parameters were compared for the six experimental conditions. The results showed that dual and multitasking as well as work interruptions triggered specific biological stress responses, namely of the SNS. However, no HPA axis as well as no immune system responses were induced by these stressors.[34]

Kaltenegger et al[30] conducted another study with the aim to assess association of technostressors with low-grade inflammation and burnout symptoms. The technostressors they chose were techno-overload, techno-complexity, techno-uncertainty, techno-insecurity, work interruptions, and multitasking. They measured high-sensitivity C-reactive protein (hs-CRP) in participants' dried blood spot obtained as blood drops after pricking participants' fingertips and collecting the sample on filter papers. Measurement of hs-CRP was done with "Human C-Reactive Protein/CRP Quantikine ELISA Kit" (IBL International). The results suggested that technostress in the form of techno- and information overload is associated with burnout symptoms. The association remained significant when work overload was included in the multivariate model.

Heart Rate

Apart from the above discussed biomarkers, heart rate may also reflect the stress level of a person. Heart rate as a biomarker for the measurement of stress has the advantage that it can be easily and constantly measured throughout the entire experiment. Under stress, the heart rate of the person rises, however, the variation of the heart rate decreases. This phenomenon can be owed to the engagement of person's sympathetic nervous system in "fight or flight" reflex which counteracts the parasympathetic nervous system. This implies that decrease in heart rate variability (HRV) is an indicator of increased stress level. Thus, heart rate variability is a better measure of stress as compared to other biomarkers as the stress is immediately reflected and measured. HRV is measured by comparing the time span between heart pulses. Electrocardiogram (ECG) is the best method to measure heart pulses, involving placing the electrodes on a person's chest and abdomen. However, measuring the HRV using ECG has its own limitations, such as high cost of the equipment, and attached electrodes obstructing the participants natural behavior and movement. To overcome these limitations, heart rate belts can be used. To collect the data most accurately, the belt is worn on the lower part of the chest, with both electrodes placed in contact with bare skin.[12]

An experiment investigated the combined influence of technostress and financial stress on users' digital financial decision-making responses. According to the results, the influence of unexpected technology behaviors is much more than perceived financial loss on physiological arousal and emotional valence (as evident by decreased SCL), feedback processing and decision-making (evident by curvilinear negative heart rate (BPM) and positive heart rate variability (HRV) responses and decreased SCL), and attentional disengagement (evident by curvilinear HRV and decreased SCL).[31]

Trimmel et al[33] studied the effect of system response time (SRT) as a stressor during human-computer interactions for information search. Three SRTs lasting 2, 10, and 22 seconds were introduced, after which heart rate, nonspecific skin conductance responses, and skin conductance level were recorded using Ag/AgCl electrodes and synapse electrode jelly. Heart rate was computed by analyzing the R-to-R interval on the electrocardiogram, which was recorded by chest leads. Skin conductance was recorded from the palmar surface above the wrist of the nondominant hand. During the experiment, participants were given three tasks that were based on searching for information on the Internet. According to results, heart rates and electrodermal activity were increased with the increase in SRT duration and did not depend on the expertise of the participants.

Baumgartner et al[52] used HRV as technostress biomarker with an intention to showcase how the preprocessing of captured data can influence the results and their interpretation, when compared to self-report data. They collected the data using a Polar H7 chest belt in combination with a smartphone app. The participants were instructed to put on the chest belt and start data collection on the smartphone app. The data was collected during working hours for one week. The evidence collected through this experiment supported the notion that NeuroIS scholars must deliberately make methodological decisions such as those related to preprocessing of physiological data. It is therefore crucial that methodology is presented with enough details in NeuroIS papers to create a better understanding of the study results and their implications.

Blood Pressure

When SNS gets activated due to stress, the physiological response of the body increases the heart rate along with contractility and vasoconstriction, leading to an increase in blood pressure. Prolonged elevation in blood pressure may lead to hypertension.[53] Rau[54] successfully used blood pressure as a biomarker for stress measurement. Hence, blood pressure is a reliable parameter for technostress assessment.

Sumiyana and Sriwidharmanely[32] measured the stress experienced by the participants after they received notification of deadline time and error messages on their computer screens during an assigned online task. Before starting the online task, the participants' blood pressure and heartbeat were determined. After the participants received the error messages during the experiment, the experimenter again measured the blood pressure and heartbeat of the participants. The results suggested that the performance of the users depends on the technostress that they experience. The users fail to advance their performance in situations where they face pressure, work overload and deadlines.

Hjortskov et al[36] evaluated the cardiovascular and subjective stress response to a combined physical and mental workload, and the effect of rest. During the experiment, computer related mental stressors were added and withdrawn from a standardized computer work session in the laboratory. Baseline blood pressure was measured before the experiment using an automatic blood pressure device (Omron 705 CP) with an arm cuff placed on the left arm in a sitting position after 10 minutes of rest. Beat-to-beat systolic and diastolic blood pressure were continuously measured during the three work sessions (introductory session, stress session, and control session), during the short breaks and during the first 4 minutes of the prolonged breaks using an automatic digital blood pressure device (2300 Finapres Blood Pressure Monitor, Ohmeda) with a finger cuff placed on the middle finger on the non-dominant hand. For heart rate variability, heart rate was analyzed using ECG. Electrodes were placed at the distal part of sternum and at the sixth rib in the left axilla. The results indicated that HRV is a more sensitive and selective marker for mental stress, because heart rate-related variables reflect a central pathway in cardiovascular control mechanisms, whereas blood pressure is more likely to be influenced by local conditions in the working muscles, partially masking the effect of changes in mental workloads.

Conclusion

The invasion of technology in the lives of human beings has led to advancement as well as stress and diseases associated with the stress. This technology induced stress is known as technostress. Research on technostress is the need of the hour and should be done extensively to be able to minimize the harmful effects of technostress and take measures to cope with it. The assessment of technostress is based on two methods, psychometric method, and biomarker measurement. Psychometric method involves the use of questionnaires, while biomarkers measurement is the method of studying body's physiological changes in response to the stress. Biomarkers are a reliable way to measure stress, the most successfully used biomarkers being skin conductance, cortisol, salivary alpha amylase, C-reactive protein, heart rate and blood pressure. Most of these biomarkers can be reliably measured non-invasively, making them even more suitable Although the studies that have used biomarkers to assess technostress are limited in number, the results promise the potential of these biomarkers to assess the technostress dependably. These have been successfully used to study the effect of inherent variables, such as personality (perception of stress, etc.) and gender on the level of technostress experienced. Biomarkers have also helped researchers in studying the effect of external variables, such as instrumental and emotional support, remote working environment, multitasking, interruptions, etc. Further, studies conducted to assess the effect of technostress on decision-making ability and efficiency have also utilized biomarkers as technostress indicators. Thus, the success of biomarker measurement in technostress research calls for more often use of these in research and experiments related to technostress in order to understand the technostress more deeply and being able to take better measures to cope with it.

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