

Information Technology-Induced Stress and Human Performance: A Critical Review

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This paper examined the relationship of information-induced stress in terms of mental workload and automation malfunction detection performance in a highly computer-aided task scenario. Modern information technology puts hard pressures on individuals' resources by demanding constant refreshing of skills. A large number of researches have been done in different areas revealing the stressful aspects of technology however, the actual discussion about the role of modern technology as a source of stress is limited. This review is an endeavor to highlight the pros and cons of the use of sophisticated automated technology. The mental workload has been considered as a consequence of highly computerized system use has been discussed in the light of various automated complex task scenarios. Moreover, the purpose of this review is also to attract human factors and ergonomics researchers to recognize this problem and to design a system that to be stress-free as possible for the users.

Keywords: Information Technology, Techno-stress, Automation, Stress, Mental workload

Presently, we are living in an 'information empowered society', encapsulated with various modern sophisticated technologies both at work place and home. Technology is spreading both vertically and horizontally throughout different organizations, also among those who have limited resources to adapt to it.

The human-machine relationships in the new technologies are significantly different from those involved in the automation and mass producing innovations that were introduced in business and industry earlier. The automated technology was primarily based on developments in engineering and broadly replaced the manual skills of the operatives. Human factor engineers mechanized human operations, thus replacing the operative, who in effect became, in most cases, an attendant. The new technologies do not replace human skills but they required different kinds of human skills.

The human operative and the machine are mutually complementary parts of a process. Work has more and more become a matter of mental rather than physical workload. This can easily be seen when we are using everyday products e.g., mobile phone, ATM or computer application software, which are sometimes not really as easy and efficient to use as they could have been, if the designer had observed some of the principles related to mental workload. Machines have taken role of human. People believed that modern computer-aided technology has reduced their mental workload but in fact, it has increased their mental workload and it also weakened their social support (Sharma, 1999).

Research from the perspective of technology as a source of stress is limited. However, some studies have been conducted. Techno-stress (synonyms for computer-related stress) refers to any

negative impact on attitudes, thoughts, behaviors, or body physiology that is caused either directly or indirectly by technology. The very gadgets designed to make life easier can actually cause an added dimension of stress. It's frustrating when the faxes, e-mails, and voice mails pile up; annoying when phones don't stop ringing; and infuriating when equipment breaks down. Moreover, Techno-stress has also been suggested as a term to describe the state of cognition and cortical arousal observed in certain employees, who are heavily dependent on computers for their work. It is suggested that organizational re-engineering and the introduction of information technologies constitute potential stressors, challenging employees' cognitive resources. Prediction is made that psychosomatic syndromes in the workplace will most likely increase in the future due to the rapid changes currently transcending working life (Arnetz & Wiholm, 1997).

The rapid spread of computer-aided system (automation) use has changed the role of a man from an active performer to a passive observer, whether it's the aviation, defense or medical diagnostic systems, or whether it's the industrial process control or just the leisure activities in the home environment. Automation has also changed person's attitude towards automated system; it places more reliance and trust on system and confidence in them (Singh, Molloy & Parasuraman, 1993).

Computer-aided system or automation in rudimentary refers to those circumstances when a machine or a computer performs a task that is otherwise performed by the human operator. Automation has been defined as 'having equipment perform a function that could be performed by the pilot manually' (Kantowitz & Sorkin, 1983). Automation further can be thought of as the 'process of allocating the activities to a machine or system to perform' (Parsons,

1985). Furthermore, Parasuraman and Riley (1997) defined automation as the execution of functions by machine (computer) which was previously carried out by a human. It is noteworthy that automation not merely signifies replacement of electrical cables by fiber optics or usage of a computer or super computer aided devices, rather it is the 'replacement of human function by machine function,' which can be elucidated in terms of human factors perspective as the 'allocation of functions' (Hancock & Scallen, 1996; Kantowitz & Sorkin, 1987). The performance of most automation depends on the interaction of people with the existing technologies. Hence, automation has grown a width with the development of technology and human brain studies (cognitive elements continuously being deciphered). The prevalence of sophisticated automated devices in aircraft and in other high-technology systems has necessitated researchers to focus on the consequences of automation on human operators. It is believed that automation can perform a function more efficiently, reliably, or accurately than the human operator. However, a potential cost of automation use has also been noted. The increasing trend headed for ever more complex technologies, which tax the human information processing system, makes it crucial to build up a meticulous understanding of the relationship between task demands, the operator's response to that demand, and the subsequent outcome reflected in the on-going level of performance efficiency.

Benefits

Automation can spare humans from carrying out dangerous operations such as the handling of hazardous materials like nuclear wastes or the recovery of material from the ocean floor after an aircraft accident. Automation can also carry out functions that are impossible for humans to perform in a timely manner (e.g., the decision to continue

or abort the takeoff of an aircraft after an engine failure; Inagaki, 1999) or impossible to perform at all due to physical disabilities (e.g., reading for the blind). Automation can take over functions that the human is capable of carrying out, but are burdensome, fatiguing or error-prone (e.g., complex mathematical calculations). In the aviation system, cockpit automation has made it possible to reduce flight times, increase fuel efficiency, navigate more effectively, and extend or improve the pilot's perceptual and cognitive capabilities (Singh, Sharma & Singh, 2005; Wiener, 1988). Automation is also considered to be more efficient, reliable and accurate than the human operator and it has been used at the highest possible level (Singh, Molloy, Parasuraman & Westerman, 1994).

Costs

The benefits of automation have been achieved after paying certain costs, for example, automation-induced complacency, increased mental workload, reduced situation awareness, skill degradation, Cognitive overload (Endsley, 1998; Singh, Parasuraman, Molloy, Deaton, & Mouloua, 1998; Parasuraman, Molloy & Singh, 1993; Weiner, 1988; Kirlik 1993).

Human Performance in Automated Systems

Over the past two decades, researchers have examined a number of different aspects of human interaction with automated systems. Automation has been found to have both beneficial and negative effects on human performance (Parasuraman & Riley, 1997; Sarter, Woods, & Billings, 1997). Although many different aspects of human performance have been examined, most empirical research has focused on four areas: mental workload; situation awareness; complacency; and skill degradation.

Certain forms of automation technology increase operator workload, or produce an

unbalanced pattern of workload over time. The automation technology which is difficult to initiate and to engage increases both cognitive workload and the physical workload of the operator (Kirlik, 1993). Unfortunately, the flight management system in aviation and in other industries where automation was originally implemented in an effort to reduce operator workload, in fact it did not do so, or merely resulted in a redistributed workload. Such systems have been referred as 'clumsy' automation (Wiener, 1988).

High-level automation of decision-making functions may also adversely affect the operator's awareness of the system and of certain dynamic features of the work environment. Humans tend to be less aware of changes in environmental or system states when those changes are under the control of another agent (whether that agent is automation or another human) than when they make the changes themselves (Endsley & Kiris, 1995; Sarter & Woods, 1995; Endsley, 1996, 1999; Kaber, Omal, & Endsley, 1999). If the decision automation consistently and repeatedly selects and executes decision choices in a dynamic environment, the human operator may lose situation awareness because he or she is not actively engaged in evaluating the information sources leading to a decision. The 1995 crash of a Boeing 757 near Cali, Colombia has been cited as an example of the adverse effect that an automated navigation system can have on the pilot's situation awareness (Endsley & Strauch, 1997).

Furthermore, if automation is highly but not perfectly reliable in executing decision choices, then the operator may not monitor the automation and its information sources and hence fail to detect the automation malfunctions. This phenomenon is known as automation-induced complacency (Billings, Lauber, Funkhouser, Lyman, & Huff, 1976; Parasuraman et al. 1993). Parasuraman, Molloy and Singh (1993) empirically

demonstrated the consequences of automation use. Participants performed a low-fidelity simulation of flight tasks, including an engine-systems task that was automated but failed from time to time. Participants were required to detect the failures and reset the system. Parasuraman et al. (1993) found that operator monitoring of the automated system was poor compared to a manual control condition when the reliability of the automation was relatively high and unchanging. The complacency effect was eliminated when the reliability of the automation was variable, alternating between high and low, or when the automated task was the only task. Parasuraman et al. (1993) attributed the poor monitoring to an attentional strategy related to operator overtrust of the automation (Lee & Moray, 1992). Complacency might reflect an "attitude towards automation" (Singh et al., 1993), which allows operator to 'trust' the automation as a strategy for dealing with high workload. Farrell and Lewandowsky (2000) suggested a computational model of the complacency effect that emphasized operator memory for automation states.

Moreover, Singh (2006) examined the relationship between subjective mental workload and automation-induced complacency. The results of the study indicated that high system reliability reduces workload, resulting in automation-induced complacency. The results also suggested that high constant system reliability (87.50%) impaired an operator's ability to monitor effectively automation failures, which are in consistent with the findings of other researchers (Bailey & Scerbo, 2007; Sharma, 1999; Singh, Molloy & Parasuraman, 1997), who reported deterioration in monitoring performance as a function of increasing system reliability.

Automation complacency has been implicated in several transportation incidents and accidents. An example was the 1995

grounding of the cruiseship Royal Majesty of the coast of Nantucket, Massachusetts. The accident occurred following the failure of a satellite-based automated navigation system and because the crew did not monitor other sources of position information (National Transportation Safety Board, 1997).

Finally, if the decision-making function is consistently performed by automation, there would come a time when the human operator would not be as skilled in performing that function (Wiener, 1988; Kaber & Riley, 1999). Degradation of cognitive skills may be particularly important following automation failure, if the human operator is required to use those skills to serve as a 'back up' to the automation.

Mental Workload and Human Performance

One particular problem associated with automated systems is that of mental workload (MWL). One of the purposes of automation is to reduce mental workload, thereby improving performance. Extremes of mental workload can create conditions of overload or underload, which may both be detrimental to performance (Wilson & Rajan, 1995). The notion of an optimal level of mental workload is based on attentional resource theory, whereby overload or underload both can cause psychological strain due to a mismatch between demands and capabilities (Gopher & Kimchi, 1989; Byrne & Parasuraman, 1996).

Overload occurs, if the demands of a task are beyond the limited attentional capacity of the operator. This can be worsened, if the operator becomes stressed, as stress is itself resource demanding and can compound cognitive interference (Matthews & Desmond, 1995). Operators and automated systems are essentially members of the same team. Effective performance in any team is dependent upon good coordination and communication. However, automated systems are inherently bad at these tasks.

The performance of the operator is hindered by the increase in processing load resulting from the additional task of collecting information about the system state. This is further complicated by the extent of the operator's knowledge about the system. In the event of manual takeover, the operator must be acutely aware of the system state, so as to match their actions to those which the computer is executing. If the user misperceives the state of the system, operator could end up in a conflict with the computer for control. In sum, lack of feedback, an increase in vigilance demands (Hancock & Verwey, 1997), and increased decision options in a given situation (Hilburn, 1997) can overload the operator.

Conversely, those susceptible to stress or fatigue may find their performance to be worse in conditions of underload, as there is a failure to mobilize compensatory effort appropriately to cope with the demands (Matthews & Desmond, 1997; Desmond, Hancock & Monette, 1998). Underload has also been associated with passivity, with optimal MWL reflecting a need to exercise a level of control (Hockey, Briner, Tattersall & Wiethoff, 1989). Young and Stanton (2002) have stated that "mental underload can lead to performance degradation due to shrinkage of attentional resources" (p.186). Indeed, underload is possibly of greater concern, as it is more difficult to detect than overload (Hancock & Verwey, 1997). There is some evidence that errors and workload are related according to a U-shaped function (Desmond & Hoyes, 1996). This suggests that operators might use less efficient strategies in such circumstances, and are failing to match their effort appropriately to the task. Thus, automation can reduce mental workload which can adversely affect performance compared to manual control. In other words, both mental underload and overload can be detrimental to performance (Hancock & Parasuraman, 1992). Moreover, Hancock

(1996) pointed out that better performance is associated with lower workload, poorer performance is associated with higher workload and no change in performance is associated with any change in workload.

Stress and Human Performance

Stress has been defined as that which is appraised as harmful, threatening, or challenging, and research into stress received a great deal of attention in the latter half of the 20th century (Cox & Griffiths, 1995). This is probably due to the fact that more people have realized the important role which stress plays in physical and psychological health, and its consequent impact on performance. Wortman and Loftus (1992) demonstrate strong evidence of a connection between stress and lowered immune system function, although it is not clear whether this is due to a direct effect on the immune system or indirect results of depression, poorer health habits etc.

It has been reported that perceived stress and perceived ability induce arousal in human increases in a linear fashion and that the relation of arousal to performance is curvilinear (McGrath, 1976). In last few decades, some cognitive psychologist have studied stress as emotional and motivational factors like intense noise (Singh, 1978; Singh, Dwivedi & Sinha, 1979, 1980), failure feedback, electric shock (Singh, 1975; Dwivedi & Singh, 1977, 1978), time of day (Singh, 1993), incentives, sleep deprivation, mental workload, and personality factors viz., introversion-extraversion (Singh, Tiwari & Singh, in press; Sharma & Singh, 1999, 2002), and job anxiety on human performance. Stimulant drug like caffeine also reported to increase cortical arousal and to decrease workload as indices of stress, resulting improvement in vigilance performance. (Tiwari, Singh & Singh, 2007; Singh, Tiwari & Singh, 2006a, 2006b).

Technology-induced Stress and Human Performance

Stress related to computer-aided technology is studied by many researchers. For example, Matthews and Desmond (1995) posited that within the context of automated systems, stress tends to have three effects: it overloads attentional capacity, disrupts executive control over selective attention, and disrupts adaptive mobilization of effort. Metzger and Parasuraman (2001) also found similar effects on driving behavior under increased attentional workload. Moreover, Wickens, Strokes, Barnett and Hyman (1991) examined the effects of stress on pilot decision making. They found three main effects of stress: (i) a reduction in cue sampling, (ii) a reduction in the resource limited capacity of working memory, and (iii) when time is reduced, a speed-accuracy trade-off in performance outcome.

Conclusions

Extension of automation technology use in working environments will continue well into the modern era. In most cases, the criteria for applying automation to new systems have been technological feasibility and cost. Moreover, it seems to have an impact on individual's resources as moderators of stress. A literature review and analysis of findings have shown that the role of modern technology as a source of stress and human performance is not straightforward. For decision and action automation however, the empirical research pertaining to situation awareness, complacency, and skill degradation suggests that high levels of automation should be implemented only for low-risk situations.

More clearly connections between technology and stress can be found when looking studies of job demands. Change is always a stressful situation and as technology changes not only the tools to work with but often the way work is organized, it is likely to

increase job demands. As literature reveals, the role of technology as a stressor is not only directly emerge from the actual use of automation technology, but also it appears indirectly from changes in demands of the task and working environment. Enabling faster processing and transformation of information, modern technology exposes employees now a day also by an ever increasing flow of information. Studies also found that excessively high levels of mental workload can lead to errors and system failure, whereas low load can lead to complacency and eventual errors.

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