Review

Overcoming COVID-19 pandemic: emerging challenges of human factors and the role of cognitive ergonomics

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ABSTRACT

The present study, an expert review, aimed to discuss the emerging challenges of overcoming COViD-19 from the perspective of human factors and the importance of cognitive ergonomics in helping to cope with the epidemic. identifying these challenges and the use of cognitive ergonomics to optimize human well-being and system performance can be effective in managing COviD-19. Generally, two main preventive approaches such as social distancing and patient care or treatment approaches are being utilized in response to COviD-19. in this paper, human factors challenges that could emerge from covid-19 preventive approaches were discussed. Social distancing forces presence and increases automated systems that lead to increases in cognitive needs, mental workload, stress, etc. Challenges of treatment and health care include the increased workload of healthcare personnel, stress, changing work systems and task allocation that led to fatigue and stress, threats to patient safety, and disruption of interpersonal interactions from a cognitive ergonomic perspective. it is concluded that the challenges of coping with COviD-19 were numerous and important from the perspective of human factors and the role of cognitive ergonomics is important in controlling the disease; hence, it should be taken into consideration.

KEYWORDS

Cognitive ergonomics; COviD-19; challenge; human factors

Relevance to human factors

This study helps to identify the emerging challenges of overcoming COVID-19 from the perspective of human factors and the importance of cognitive ergonomics. This study also determined the role of Cognitive Ergonomics in controlling the covid-19 pandemic.

Introduction

New coronavirus, Coronavirus Disease-2019 (COVID-19), was first reported as a causative agent of respiratory disease in Wuhan, China, in December 2019 (Zhu et al. 2020). The World Health Organization (WHO) reported it as a pandemic on March 11, 2020 (Cucinotta and Vanelli 2020). From the beginning of the coronavirus to the time of writing this article (November 2020), the virus infected more than 60 million people worldwide and killed about 1.5 million people (Silva et al. 2020; Zarrabian and Hassani-Abharian 2020).

The clinical studies indicate that the virus is transmitted from person to person and has no specific treatment (Johansson et al. 2021). Therefore, the WHO has recommended the social distance strategy, patient care, and quarantine as basic strategies in preventing the disease (Wiersinga et al. 2020).

In response to COVID-19, there are a variety of solutions such as the use of masks, vaccination, hands sanitization, social distancing and patient care and treatment. However, emphases are placed on two preventive approaches, including social distancing and patient care and treatment (Wiersinga et al. 2020). On the other hand, it seems these induce more human factors problems and need more attention. Applying these principles has led to changes in lifestyle and work systems so that most physical activities have been limited and the ways of working have changed. Some of the changes will be sustained in the future and even after the coronavirus epidemic due to its economic benefits over the traditional method (Manzanedo and Manning 2020; Silva et al. 2020). Changes in lifestyles and work systems can affect human factors such as how humans interact with other components of the system (Carayon and Smith 2000). Given the main purpose of ergonomics and engineering of human factors, as the examination of human interactions with other system components and improvement of these interactions (Karwowski 2005), the present study aimed to interpret the challenges posed by the outbreak of COVID-19 on human factors and determine the role of cognitive ergonomics to improve human performance in a crisis.

Background

According to the International Ergonomics Association (IEA), cognitive ergonomics is a branch of human factor science and examines the interaction of human cognitive processes, such as perception, memory, reasoning, and motor response, with other elements of the system (Karwowski 2012).

Cognitive ergonomics plays a key role in the human-system design and addresses issues including mental workload, decision making, human-computer interaction, human reliability, stress, and human training that affect the human-system design. Therefore, cognitive ergonomics is the study of human cognition in the workplace and operational settings to optimize human well-being and system performance (Zachary et al. 2001). Using the interventions, namely the user-centered design of human-machine interaction and human-computer interaction (HCI), design of information technology systems that support cognitive tasks (e.g., cognitive artifacts), development of training programs, work redesign to manage cognitive workload, and increasing the human reliability, the cognitive ergonomics seeks to optimize human-system performance (Zachary et al. 2001).

Features of the COVID-19 pandemic include changes in many systems and the emergence of new work systems such as teleworking, e-learning, and tele-teaching, as well as changes in health care systems (Machado et al. 2020; Radha et al. 2020; Tavares et al. 2020). Changes in systems also change the human-system interaction that often reduces personal and team performance (Karwowski 2012). Ergonomics and human factors specialists can help develop appropriate solutions to support the individual and team performance in critical situations such as the COVID-19 epidemic (Gurses et al. 2020).

Some cognitive ergonomics strategies can be developed very practically and quickly with minimal resources (e.g. sign design, checklists, and work instructions to support individual or team cognitive work while facing the COVID-19 patients), and others need more time

and examination, such as creating new guidelines for interacting more safely with critical situations and developing highly usable software for teaching and learning (Gurses et al. 2020).

Study methodology

This is an expert review study that was conducted to document issues relevant to human factors and ergonomics induced by the covid-19 outbreak. A standard literature search was performed using three pertinent search engines for scientific and academic research, i.e., Scopus, Google Scholar, and ISI Web of Science, which hold the world's largest citation databases. The search was set from the date of the first relevant article until the end of 2020. The following keywords were used at each query: 1) human factors, 2) cognitive ergonomics 3) COVID-19.

COVID-19 human factors challenges

The COVID-19 crisis has posed several challenges from the perspective of human factors. We must focus on coping responses to the disease and the resulting changes in human behavior to identify these challenges. There are two strategies, including prevention and treatment of patients to deal with this disease. Given the person-person transmission of COVID-19, social distancing is an important strategy that has been focused on by the World Health Organization since its emergence. Social distancing has caused numerous changes in work, teaching, learning, and human social interactions; hence, its effects on human factors should be studied and examined (Wiersinga et al. 2020). Table 1 presents some challenges of human factors resulting from the use of coping strategies with the diseases as follows (Gurses et al. 2020; Radha et al. 2020; Ting et al. 2020).

Teleworking and reducing the labor force presence in the workplace

Teleworking refers to a significant time for working away from caregivers or the official workplace (Wiersinga et al. 2020). Since the outbreak of the COVID-19 epidemic, teleworking has become the norm for millions of workers worldwide. Preliminary estimates indicate that about 40% of workers in European countries have turned to telework (Milasi,

Table 1. coViD-19 human factors challenges (Zachary et al. 2001; hignett, Welsh, and Banerjee 2021; Zarrabian and hassani-abharian 2020).

coViD-19 prevention strategies	human factors challenges
Teleworking	stress, mental fatigue, mental workload, human-computer interaction (hci) (Zachary et al. 2001)
e-learning and tele-teaching	satisfaction, usability, performance, learner's capability Distractions, frustration, anxiety and confusion, lack of personal/physical attention (Zachary et al. 2001)
automation	Task allocation, human-automation interaction, cognitive failure (hignett, Welsh, and Banerjee 2021)
reducing the labor force presence	Task allocation, fatigue, human error, workload, performance (Zarrabian and hassani-abharian 2020)
Providing the health care	stress, workload, length of shift, safety patient (Zarrabian and hassani-abharian 2020)

González-Vázquez, and Fernández-Macías 2020). Studies indicate that teleworking increased by 3% between 2012 and 2016, while the recent JRC study has estimated that the coronavirus has increased teleworking by 15 per cent compared to before its outbreak (Milasi, González-Vázquez, and Fernández-Macías 2020). Before the coronavirus pandemic, highly-skilled professionals and managers, such as IT managers and business and legal managers, worked remotely, but the spread of the pandemic has also led to the spread of teleworking in other jobs (e.g. training, office working, accounting, Consulting) (Milasi, González-Vázquez, and Fernández-Macías 2020). Along with benefits such as independence in doing work, flexibility in doing work, and time management capabilities, teleworking has challenges such as a sense of isolation and the need for self-discipline at work by the workers (Daniels, Lamond, and Standen 2001; Harpaz 2002). Teleworking is highly dependent on information and communication technology; hence, many businesses require software platforms to do teleworking (Daniels, Lamond, and Standen 2001; Harpaz 2002). Significant ergonomic challenges from a cognitive ergonomic perspective include anxiety and stress due to isolation and loneliness, poor mental health conditions, work stress due to lack of support from other colleagues, lack of concentration due to the loud voice of family members, or social activities outside the home. A low level of certainty from a remote worker's work changes the duration of work and sometimes the inability of a remote worker to solve their problems that can increase mental fatigue and mental workload (Daniels, Lamond, and Standen 2001). Furthermore, poor usability of software and human-computer interfaces increases mental workload and mental fatigue, and the workers' performance (Golden and Veiga 2008). Due to the application and goals of cognitive ergonomics, this discipline of human factor engineering can play an important role in reducing telework stressors, improving health, and improving human-computer interaction and performance. Therefore, the increase and expansion of teleworking make the role of cognitive ergonomics important in improving working conditions (Karwowski 2012; Gurses et al. 2020).

E-Learning and tele-teaching

COVID-19 probably has a great effect on learning and teaching because the global policy of social distance has forced millions of school students, university students, and teachers to use e-learning and tele-teaching (Adedoyin and Soykan 2020). Before the COVID-19 pandemic, e-learning was also relatively common, but this disease has increasingly catalyzed the conversion of traditional teaching and learning to digital and e-learning (Mahdizadeh, Biemans, and Mulder 2008; Radha et al. 2020).

In this regard, the use of educational applications, software, educational simulators in medicine and engineering, and other virtual infrastructures has become increasingly widespread to facilitate e-learning and tele-teaching (Mian and Khan 2020). The quality of teaching and learning in e-learning and virtual systems depends on the usability of resources and interactive facilities in them, such as models and blackboards (Pal and Vanijja 2020).

Studies indicate that the rapid transition from traditional education to online education in the Covid-19 crisis has taken place without planning and study, and this questions its effectiveness (Pal and Vanijja 2020). According to previous research, the usability of e-learning and tele-teaching systems is the most important factor in improving the users' performance and is affected by factors such as effectiveness, perceived usefulness, engagement,

ease of use, and environment (Pal and Vanijja 2020). The non-usability of these virtual training systems may lead to the unwillingness to use the systems and the reduction of productivity and satisfaction (Nagy 2009).

Factors affecting human interaction with that product should be taken into consideration to improve the usability of a product. Therefore, there is a need to observe the principles of cognitive ergonomics and pay attention to human needs in designing virtual platforms used in teaching and learning (Jordan 2002). Despite the existence of studies in this field, there are many challenges in this regard due to the rapid expansion of the use of these systems so that cognitive ergonomics can answer them; hence, a great number of studies are necessary to better understand the existing challenges and solve them. There is a need for investigating the cognitive skills and competencies such as problem-solving, information management, and collaboration with respect to effectiveness, efficiency, and ethics for optimal use of e-learning and tele-teaching systems so that the cognitive ergonomics can focus on them (Gutman and Schoon 2013). The characteristics of e-learning and e-teaching technology and the barriers to using virtual methods in teaching and learning need further study. Making these technologies more usable and removing barriers to optimal use, reducing the time of learning to work with educational software, and increasing satisfaction and performance are other research challenges for which cognitive ergonomics can find a suitable answer.

Increasing the automation

There has been significant progress in automation over the past decade. Many tasks, which were not previously known automatically, can be now performed without manpower, and the number of industrial robots has increased dramatically. Advanced technologies have largely replaced the daily tasks of low-skilled workers (Gutman and Schoon 2013). During the COVID-19 epidemic, automation has increased dramatically to reduce interaction between people and reduce the risk of infection (Figure 1). The cost-effectiveness, ease of use, and enjoyment of automation will also increase in the future. For instance, Amazon opened its first cashless store in the UK, and also mobile robots began providing services for guests in Hong Kong (Milasi, González-Vázquez, and Fernández-Macías 2020).

Automation raises new challenges of cognitive ergonomics. Human-machine interaction in automation systems is different from non-automated and conventional systems, and the human supervisory role increases; hence, identifying and analyzing emerging cognitive needs due to automation is the first challenge that cognitive ergonomics must address. Cognitive ergonomics should develop more comprehensive models and techniques in order to achieve this. Automation creates non-intuitive behaviors in individuals, resulting in higher mode errors and misuse or non-use of automation systems. Therefore, identifying and describing emerging behaviors is another challenge of increasing automation that cognitive ergonomics must answer (Lee 2001).

Impact on health care systems

The impact on the performance of health care systems is a major challenge posed by the COVID-19 pandemic. Health care systems are not sufficiently designed to support human

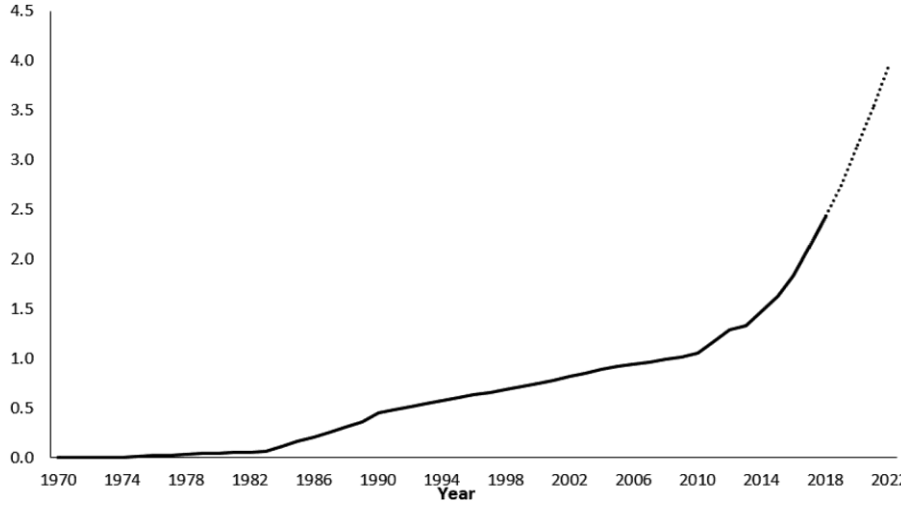

Figure 1. Worldwide stock of operative industrial robots in millions of units over time (Bloom and Prettner 2020).

performance in critical situations. The increase in workload, the emergence of new tasks, creation of new guidelines, crisis stress, the long-term use of personal protective equipment, the increase in work shifts, and the need for new training are some effects of this epidemic on health care systems in terms of human factors, leading to the lower performance, higher fatigue and mental and physical workload, interference in interpersonal interactions, and the health care provider and patients, and ultimately an adverse effect on the safety of patients and health care workers (Gurses et al. 2020; Hignett, Welsh, and Banerjee 2021).

Furthermore, the complexities of human behavior and cognition have not been exhaustively studied in facing critical situations such as coping with COVID-19. Therefore, according to studies and evidence of human and ergonomic factors, the prevalence of COVID-19 seriously affects the personal and team performance of health care workers in high-risk conditions (Sasangohar et al. 2020).

The role of cognitive ergonomics

Cognitive ergonomics offers various contributions to address human factors challenges during the COVID pandemic. Some of these contributions are highlighted below based on the literature review.

Assessment of the usability of instructions, software, and applications

The main emerging challenge arising from the outbreak of COVID-19 is the expansion of using software and applications as well as general and specific guidelines for the prevention of COVID-19 (Bokolo 2021). Due to the explosive prevalence of this disease and its risks, most of these tools have been developed regardless of their usability, which can affect human performance and satisfaction. For instance, guidelines published by CDC were inappropriate

in the Ebola epidemic, so they were evaluated and improved by 40 human factor specialists (Gurses et al. 2020).

The purpose of usability testing is to evaluate user interfaces and ensure system quality. Systems with better usability lead to higher human performance and satisfaction with interaction with them (Lin, Choong, and Salvendy 1997).

Ergonomics professionals can evaluate and improve the usability of software and applications as well as public information and operating instructions (Gurses et al. 2020).

Re-conceptualizing expertise development

The prevalence of COVID-19 has led to new skill-based and cognitive needs to perform certain tasks. Specialists must have the ability and readiness to respond to the emerging needs of their tasks. For example, the nurses' and physicians' duties have changed based on new protocols in treatment as well as their self-protection, or crisis management specialists have faced new tasks. Therefore, it is necessary to identify skill and cognitive needs to improve performance and identify its determinants (Bickley and Torgler 2020; Gurses et al. 2020). Cognitive ergonomics can use methods and techniques such as cognitive work analysis (CWA) and Applied Task Cognitive Analysis to examine tasks and determine their necessary cognitive and skill needs (Sanderson et al. 1999). We need to identify what abilities, skills, and knowledge structures should be obtained in response to COVID-19. These efforts can improve performance by overcoming COVID-19 as well as skill training and more appropriate task allocation between humans and machines.

Managing swarms of automation

The increasing use of automation systems and consequently the increasing complexity of systems are some challenges in the COVID-19 crisis (Milasi, González-Vázquez, and Fernández-Macías 2020). Studies have shown that as technology becomes more sophisticated, because of the problems of appropriate function allocation and human mental workload increasing, safety and efficiency of the systems decreased (Lee 2001).

Addressing these problems requires the use of cognitive ergonomics. Identifying the monitoring needs created by automation is the first mission of cognitive ergonomics in solving automation problems. Due to dynamic changes in human-automation interaction, there is a need for the use of dynamic models to understand human interaction with automation systems and that cognitive ergonomics plays a key role in creating such models. Therefore, cognitive ergonomics should help develop and understand the basic cognitive relating to automation management as well as tools for creating interaction and dynamic decision making with an automation system. For example, cognitive ergonomics can determine cognitive skills and the type of education that need to improve human performance or enhance attention and help in decision making by better design (Lee 2001).

Improving system-wide communication and coordination

COVID-19 has increased the interdisciplinary, professional, and specialized communications in the world. Most of these communications are done via social networks such as

WhatsApp and Facebook. Even though previous studies have found such communication useful, non-technical skills such as stress management, situational awareness, and communication coordination in virtual communication are more vulnerable than the traditional ways. Therefore, cognitive ergonomics plays an important role in identifying communication and coordination impairment in the crisis caused by COVID-19 and for the establishment of appropriate systems (Table 2). For instance, the use of artificial intelligence and automation systems can help overcome this challenge (Sasangohar et al. 2020).

Optimization of e-learning, e-meeting, e-training, and teaching methods

The importance of distance and online education was highlighted in the current pandemic. The World Health Organization and the National Institutes of Health have also tried to use online training and found this method effective in controlling the pandemic (Dhawan 2020). Despite efforts to improve online teaching, there are still significant gaps in the use of an agile, well-functioning online education system. These challenges can be overcome by human-centered and collaborative design.

Improving the proper interaction between learners and teachers and online education systems is the most important issue that cognitive ergonomics can help to improve. Ergonomics experts can also contribute to the way of presenting useful educational content. Identifying the weaknesses of systems in terms of usability and improving them are other abilities of ergonomics experts. Therefore, cognitive ergonomics can play an important and

Table 2. Cognitive ergonomics contributions and relevant methodologies for outbreak management.

cognitive ergonomics informed approaches and strategies	sample methods and intervention examples
Developing/adapting the user-friendly cognitive tools checklists to operationalize the process (sasangohar et al. 2020)	Designing the visuals, scripts, checklists to support cognitive work based on usability and other cognitive ergonomics-based design principles
improving the usability of any guidance documents and guidelines, and software, applications (sasangohar et al. 2020)	conducting the practical and formative usability evaluations (e.g., heuristic analysis conducted by an ergonomics expert within 15 min or so)
optimization of e-learning, e-meeting, e-training, and teaching methods (sasangohar et al. 2020)	Design of human-centered, usable, dynamic, interesting, and interactive e-learning platforms, usability evaluation
identifying the information requirements to support front-line (sasangohar et al. 2020)	cognitive task analysis methods and techniques such as cognitive work analysis and mental workload assessment.
Developing the mechanisms to communicate efficiently across people, time, and locations (sasangohar et al. 2020)	using the human-centered design approaches to iteratively develop and pilot usable communication tools and mechanisms, and effective messaging strategies
improving system-Wide communication and coordination (sasangohar et al. 2020)	cognitive task analysis, situation awareness assessment, stress management, using near-Field-communication (nFc)
managing swarms of automation (sasangohar et al. 2020)	Developing an understanding of the basic cognitive demands associated with managing automation, tools that consider the dynamics of the interaction, and constructs that address the dynamic decision making that governs reliance.
re-conceptualizing the expertise Development (sasangohar et al. 2020)	Determining the specific abilities, skills, and knowledge structures in the coViD responses.

effective role in improving the quality of online and distance education. Farzan Sasan-Gohar et al. considered the timely context-oriented approach as a way of improving online education in the COVID-19 crisis (Sasangohar et al. 2020). According to them, the attitude could be an appropriate model for education without lowering educational standards. Furthermore, Olasile Babatunde Adedoyin and Emrah Soykan believe that the conversion of traditional education into online education systems due to COVID-19 has rushed and performed without any study; hence, there is a need for much research to review and remove the challenges (Dhawan 2020). Cognitive ergonomics is an effective science in solving challenges.

Limitation

Overall, this study provides a thorough overview of cognitive ergonomic challenges in the face of the COVID-19 pandemic. However, this study has two main limitations that need to be mentioned for future studies. Firstly, due to the limited number of related studies, the issues that are discussed are narrow. Secondly, this study focuses only on human factors that can be solved by cognitive ergonomics, and there are many more areas where HFE can contribute to the management of global pandemics that need to be explained in another study. There is a need for more original research studies and systematic reviews to explain and justify correctly ergonomics issues that are effective in the COVID-19 pandemics in the future.

Conclusion

Researchers in all disciplines are seeking to help control COVID-19. The present study specifically aimed to explain the role of cognitive ergonomics in helping control COVID-19 and its effects. The study indicated the obvious role of cognitive ergonomics in the process of confronting the COVID-19 pandemic. Overcoming COVID-19 is associated with many challenges in terms of human factors and ergonomics. There is a need for various sciences, one of which is cognitive ergonomics, to decrease such challenges. Increasing teleworking, e-learning, distance therapy, automation, and reducing the number of the labor force are the main consequences of overcoming this disease, and they have converted the physical work into cognitive and much reliance of activities on the human mind. It has increased the mental workload, the need for decision-making, the higher role of human supervision due to the automation of some activities, problem-solving, etc., that may result in higher stress, mental work, mental fatigue, lower performance, higher human error, and lower safety.

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References

Adedoyin, O. B., and E. Soykan. 2020. "Covid-19 Pandemic and Online Learning: The Challenges and Opportunities." *Interactive Learning Environments* 2020: 1–13. doi:10.1080/10494820.2020.1813180.

Bickley, S. J, and B. Torgler. 2020. "A Systematic Approach to Safety Incidents in Public Health: Applying the Human Factors Analysis and Classification System to COVID-19." CREMA Working Paper.

Bloom, D., and K. Prettner. 2020. "The Macroeconomic Effects of Automation and the Role of COVID-19 in Reinforcing Their Dynamics." VOX CEPR Policy Portal 25.

Bokolo, A. J. 2021. "Exploring the Adoption of Telemedicine and Virtual Software for Care of Outpatients during and after COVID-19 Pandemic." *Irish Journal of Medical Science* 190 (1): 1–10. doi:10.1007/s11845-020-02299-z.

Carayon, P., and M. J. Smith. 2000. "Work Organization and Ergonomics." *Applied Ergonomics* 31 (6): 649–662. doi:10.1016/S0003-6870(00)00040-5.

Cucinotta, D., and M. Vanelli. 2020. "WHO Declares COVID-19 a Pandemic." *Acta Bio Medica: Atenei Parmensis* 91 (1): 157.

Daniels, K., D. Lamond, and P. J. Standen. 2001. "Teleworking: Frameworks for Organizational Research." *Journal of Management Studies* 38 (8): 1151–1185. doi:10.1111/1467-6486.00276.

Dhawan, S. J. 2020. "Online Learning: A Panacea in the Time of COVID-19 Crisis." *Journal of Educational Technology Systems* 49 (1): 5–22. doi:10.1177/0047239520934018.

Golden, T. D., and J. F. Veiga. 2008. "The Impact of Superior–Subordinate Relationships on the Commitment, Job Satisfaction, and Performance of Virtual Workers." *The Leadership Quarterly* 19 (1): 77–88. doi:10.1016/j.leaqua.2007.12.009.

Gurses, A. P., M. M. Tschudy, S. McGrath-Morrow, A. Husain, B. S. Solomon, K. A. Gerohristodoulos, and J. M. Kim. 2020. "Overcoming COVID-19: What Can Human Factors and Ergonomics Offer?" *Journal of Patient Safety and Risk Management* 25 (2): 49–54. doi:10.1177/2516043520917764.

Gutman, L. M., and I. Schoon. 2013. "The Impact of Non-Cognitive Skills on Outcomes for Young People." *Education Endowment Foundation* 59 (22.2): 2019.

Harpaz, I. J. 2002. "Advantages and Disadvantages of Telecommuting for the Individual, Organization and Society." *Work Study* 51 (2/3): 74–80.

Hignett, S., R. Welsh, and J. Banerjee. 2021. "Human Factors Issues of Working in Personal Protective Equipment during the COVID-19 Pandemic." *Anaesthesia* 76 (1): 134–135. doi:10.1111/anae.15198.

Johansson, M. A., T. M. Quandelacy, S. Kada, P. V. Prasad, M. Steele, J. T. Brooks, R. B. Slayton, M. Biggerstaff, and J. C. Butler. 2021. "SARS-CoV-2 Transmission from People without COVID-19 Symptoms." *JAMA Network Open* 4 (1): e2035057–e2035057. doi:10.1001/jamanetworkopen.2020.35057.

Jordan, P. W. 2002. *Designing Pleasurable Products: An Introduction to the New Human Factors*. Boca Raton: CRC Press.
Karwowski, W. 2005. "Ergonomics and Human Factors: The Paradigms for Science, Engineering, Design, Technology and Management of Human-Compatible Systems." *Ergonomics* 48 (5): 436–463. doi:10.1080/00140130400029167.
Karwowski, W. 2012. "The Discipline of Human Factors and Ergonomics." In *Handbook of Human Factors and Ergonomics*, 4th ed., 3–37. Hoboken: Wiley.
Lee, J. D. 2001. "Emerging Challenges in Cognitive Ergonomics: Managing Swarms of Self-Organizing Agent-Based Automation." *Theoretical Issues in Ergonomics Science* 2 (3): 238–250. doi:10.1080/14639220110104925.
Lin, H. X., Y.-Y. Choong, and G. Salvendy. 1997. "A Proposed Index of Usability: A Method for Comparing the Relative Usability of Different Software Systems." *Behaviour & Information Technology* 16 (4–5): 267–277. doi:10.1080/014492997119833.
Machado, R. A., P. R. F. Bonan, D. E. d C. Perez, and H. Martelli Júnior. 2020. "COVID-19 Pandemic and the Impact on Dental Education: Discussing Current and Future Perspectives." *Brazilian Oral Research* 34: e083.
Mahdizadeh, H., H. Biemans, and M. Mulder. 2008. "Determining Factors of the Use of e-Learning Environments by University Teachers." *Computers & Education* 51 (1): 142–154. doi:10.1016/j.compedu.2007.04.004.
Manzanedo, R. D., and P. Manning. 2020. "COVID-19: Lessons for the Climate Change Emergency." *The Science of the Total Environment* 742: 140563. doi:10.1016/j.scitotenv.2020.140563.
Mian, A., and S. Khan. 2020. "Medical Education during Pandemics: a UK Perspective." *BMC Medicine* 18 (1): 100.
Milasi, S. I. González-Vázquez, and E. Fernández-Macías. 2020. "Telework in the EU Before and After the Covid-19: Where We Were, Where We Head to." Science for Policy Briefs.
Nagy, N. S. 2009. "Evaluating the Usability of Information Systems in the International Space Station Integration Processes." Northcentral University.
Pal, D., and V. Vanijja. 2020. "Perceived Usability Evaluation of Microsoft Teams as an Online Learning Platform during COVID-19 Using System Usability Scale and Technology Acceptance Model in India." *Children and Youth Services Review* 119: 105535. doi:10.1016/j.childyouth.2020.105535.
Radha, R., K. Mahalakshmi, V. S. Kumar, and A. R. Saravanakumar 2020. "E-Learning during Lockdown of Covid-19 Pandemic: A Global Perspective." *International Journal of Control and Automation* 13 (4): 1088–1099.
Sanderson, P., N. Naikar, G. Lintern, and S. Goss. 1999. "Use of Cognitive Work Analysis across the System Life Cycle: From Requirements to Decommissioning." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 43 (3): 318–322. doi:10.1177/154193129904300340.
Sasangohar, F., J. Moats, R. Mehta, and S. C. Peres. 2020. "Disaster Ergonomics: Human Factors in COVID-19 Pandemic Emergency Management." *Human Factors* 62 (7): 1061–1068. doi:10.1177/0018720820939428.
Silva, P. C., P. V. Batista, H. S. Lima, M. A. Alves, F. G. Guimarães, and R. C. P. Silva. 2020. "COVID-ABS: An Agent-Based Model of COVID-19 Epidemic to Simulate Health and Economic Effects of Social Distancing Interventions." *Chaos, Solitons, and Fractals* 139: 110088. doi:10.1016/j.chaos.2020.110088.
Tavares, F., E. Santos, A. Diogo, and V. Ratten. 2020. "Teleworking in Portuguese Communities during the COVID-19 Pandemic." *Journal of Enterprising Communities: People and Places in the Global Economy* 15 (3): 334–349.
Ting, D. S. W., L. Carin, V. Dzau, and T. Y. Wong. 2020. "Digital Technology and COVID-19." *Nature Medicine* 26 (4): 459–461. doi:10.1038/s41591-020-0824-5.
Wiersinga, W. J., A. Rhodes, A. C. Cheng, S. J. Peacock, and H. C. Prescott. 2020. "Pathophysiology, Transmission, Diagnosis, and Treatment of Coronavirus Disease 2019 (COVID-19): A Review." *JAMA* 324 (8): 782–793. doi:10.1001/jama.2020.12839.

Zachary, W., G. E. Campbell, K. R. Laughery, and F. Glenn. 2001. "The Application of Human Modeling Technology to the Design, Evaluation and Operation of Complex Systems." *Advances in Human Performance and Cognitive Engineering Research* 1: 201–250.

Zarrabian, S., and P. Hassani-Abharian. 2020. "COVID-19 Pandemic and the Importance of Cognitive Rehabilitation." *Basic and Clinical Neuroscience* 11 (2): 129–132. doi:10.32598/bcn.11.covid19.194.5.

Zhu, N., D. Zhang, W. Wang, X. Li, B. Yang, J. Song, X. Zhao, et al. 2020. "A Novel Coronavirus from Patients with Pneumonia in China, 2019." *New England Journal of Medicine* 382 (8): 727–733. doi:10.1056/NEJMoa2001017.