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Human Systems Integration: A Review of Concepts, Applications, Challenges, and Benefits

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Abstract:
This paper provides a review of the concepts, applications, and challenges of Human Systems Integration (HSI). HSI is a multidisciplinary field that aims to optimize the performance of human-machine systems by considering the characteristics and capabilities of both human operators and technological systems. The review begins with a discussion of the fundamental concepts of HSI, including human factors engineering, human-computer interaction, and cognitive engineering. It then examines the application of HSI in specific domains such as aviation, transportation, and medicine. The paper concludes by discussing the challenges and future directions of HSI research. The paper highlights the importance of considering the cognitive and affective aspects of human operators in the design of systems and the challenges related to the integration of multiple systems and the consideration of social and organizational factors.
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1. Introduction:

Human Systems Integration (HSI) is a multidisciplinary field that aims to optimize the performance of human-machine systems by considering the characteristics and capabilities of both human operators and technological systems (Boy, 2020). HSI is of particular importance in the design and operation of complex systems such as aviation, transportation, medicine, and military operations. Recent advances in technology have led to the development of highly automated systems that require minimal human involvement (Booher, 2003). However, the increasing complexity of these systems has also highlighted the importance of considering the human element in their design and operation (Ahmed & Miller, 2022). HSI seeks to understand how human operators interact with technology and how to design systems that enhance human performance while minimizing errors and accidents (Ahmed, 2022).

The concept of HSI has its roots in the field of ergonomics, which focuses on the design of equipment and work environments to fit the physical and psychological characteristics of human operators. However, HSI has evolved to encompass a broader range of issues, including the integration of multiple systems, the management of information, and the development of interfaces that are intuitive and easy to use (Stonebraker & Hellerstein, 2001).

In the field of medicine, HSI research has focused on the design of clinical decision support systems that take into account the cognitive and affective aspects of physicians and other healthcare providers (Ahmed & Miller, 2022; Patel et al., 2002)

The field of HSI also faces a number of challenges. One major challenge is the integration of multiple systems, which can lead to increased complexity and the potential for errors and accidents. Researchers have also highlighted the importance of considering the social and organizational factors that can impact the performance of human-machine systems (Al Hosani et al., 2022).

Finally, the paper will conclude by discussing the challenges and future directions of HSI research as the recent research in HSI has emphasized the importance of considering the cognitive and affective aspects of human operators in the design of systems. For example, in the field of aviation, researchers have focused on the development of cockpit displays and procedures that take into account the cognitive and perceptual limitations of pilots (Ahmed et al., 2023; Endsley, 1988). In the field of transportation, researchers have studied the impact of advanced driver assistance systems on driver behavior and performance (Lyu et al., 2019).

2. Conceptual Foundations:

The conceptual foundations of HSI can be traced back to the field of ergonomics, which focuses on the design of equipment and work environments to fit the physical and psychological characteristics of human operators (Helander, 1997). However, HSI has evolved to encompass a broader range of issues, including the integration of multiple systems, the management of information, and the development of interfaces that are intuitive and easy to use (Al Hosani et al., 2022; Stonebraker & Hellerstein, 2001).

One of the key concepts in HSI is human factors engineering (HFE). HFE is the application of knowledge about human capabilities and limitations to the design of equipment and work environments (Miller, 1999). The goal of HFE is to ensure that systems are designed in a way that takes into account the physical and cognitive abilities of human operators. Research in HFE has focused on understanding the human factors that contribute to accidents and errors, and how to design systems that minimize these risks (Miller, 1999).

Another key concept in HSI is human-computer interaction (HCI). HCI is the study of how people interact with computers and other technology, with the goal of making these interactions more efficient and effective (Issa & Isaias, 2022). HCI research has focused on developing interfaces that are easy to use, understand, and navigate. This includes the use of natural language processing, gesture recognition, and other techniques to make computer interactions more intuitive and user-friendly (Rautaray & Agrawal, 2012).

Cognitive engineering is also a fundamental concept in HSI. Cognitive engineering is the application of cognitive psychology to the design of human-machine systems. The goal of cognitive engineering is to understand how human operators process and use information, and how to design systems that take into account these cognitive processes (Parasuraman et al., 2008). Research in cognitive engineering has focused on understanding how human operators perceive, understand, and use information in complex systems (Blomberg, 2011; Parasuraman et al., 2008).

The field of HSI also involves the integration of multiple systems, which can lead to increased complexity and the potential for errors and accidents. Researchers have also highlighted the importance of considering the social and organizational factors that can impact the performance of human-machine systems (Helander, 2014).

In the field of aviation, HSI research has focused on the development of cockpit displays and procedures that take into account the cognitive and perceptual limitations of pilots (Wiener & Nagel, 1988). In the field of transportation, researchers have studied the impact of advanced driver assistance systems on driver behavior and performance (Lyu et al., 2019). In the field of medicine, HSI research has focused on the design of clinical decision support systems that take into account the cognitive and affective aspects of physicians and other healthcare providers (Bensing, 2000).

One of the challenges in HSI is the integration of multiple systems, which can lead to increased complexity and the potential for errors and accidents. Researchers have also highlighted the importance of considering the social and organizational factors that can impact the performance of human-machine systems (Denyer et al., 2008).

In order to address these challenges, researchers have developed methods for assessing the performance of human-machine systems, such as Situation Awareness Global Assessment Technique (Kaber et al., 2000) and the Human-Automation Interaction (HAI) framework(Kaber et al., 2000). These methods provide a systematic way to evaluate the performance of human-machine systems and identify areas for improvement.

Another challenge in HSI is the development of effective human-machine interfaces. As technology becomes increasingly complex, it is essential to design interfaces that are easy to use, understand, and navigate. Researchers have developed a number of techniques to address this challenge, such as the use of natural language processing, gesture recognition, and other techniques to make computer interactions more intuitive and user-friendly (Pickering et al., 2007; Vicente & Rasmussen, 1990)

It is also important to consider the social and organizational factors that can impact the performance of human-machine systems. Researchers have highlighted the importance of considering the impact of organizational culture, team dynamics, and communication on the performance of human-machine systems (Martínez-Caro et al., 2020). In order to address these challenges, researchers have developed methods for assessing the social and organizational factors that impact human-machine systems, such as the Organizational Safety Climate (OSC) framework (Curcuruto et al., 2018).

3. Human Systems Integration Applications in Transportation:

The transportation sector is one of the most important industries in the world, and the safety and efficiency of transportation systems are crucial for economic and social development. Therefore, the application of HSI in transportation is of great significance for improving transportation safety, efficiency, and sustainability.

One of the most important applications of HSI in transportation is the design and evaluation of Advanced Driver Assistance Systems (ADAS) (Möller et al., 2019). ADAS are electronic systems that assist drivers in various driving tasks such as braking, steering, and lane keeping (Möller et al., 2019). ADAS technologies have been developed to reduce the number of accidents caused by human errors and improve the efficiency of transportation systems (Stanton & Salmon, 2009). However, the effectiveness of ADAS depends on the interaction between drivers and the systems, and the design of ADAS should take into account the human factors, such as perception, cognition, and behavior. Research in HSI has focused on understanding how drivers interact with ADAS, and how to design ADAS that enhance driver performance while minimizing errors and accidents (Davidse, 2006).

Another important application of HSI in transportation is the design and evaluation of Human-Machine Interfaces (HMI) for vehicles. The HMI is the interface between the driver and the vehicle, and it is critical for the safe and efficient operation of the vehicle (Cunningham & Regan, 2015). The HMI should be designed to take into account the human factors, such as perception, cognition, and behavior, and it should be easy to use, understand, and navigate (Forlizzi et al., 2010). Research in HSI has focused on developing HMI that are intuitive and user-friendly, such as the use of natural language processing, gesture recognition, and other techniques to make vehicle interactions more intuitive and user-friendly (Sharma & Verma, 2015).

Another application of HSI in transportation is the design and evaluation of Intelligent Transportation Systems (ITS). ITS are systems that use advanced technologies to improve the safety, efficiency, and sustainability of transportation systems (Morrissett et al., 2019). ITS technologies include traffic management systems, vehicle-to-vehicle and vehicle-to-infrastructure communication systems, and advanced navigation systems. The effectiveness of ITS depends on the interaction between drivers and the systems, and the design of ITS should take into account the human factors, such as perception, cognition, and behavior. Research in HSI has focused on understanding how drivers interact with ITS, and how to design ITS that enhance driver performance while minimizing errors and accidents (Guériau et al., 2016).

It is important to note that the integration of multiple systems and the consideration of social and organizational factors are also challenges in HSI in transportation. Researchers have highlighted the importance of considering the social and organizational factors that can impact the performance of human-machine systems (Booher, 2003). In order to address these challenges, researchers have developed methods for assessing the performance of human-machine systems, such as Situation Awareness Global Assessment Technique (SAGAT) (Kaber et al., 2000) and the Human-Automation Interaction (HAI) (Kaber et al., 2000). These methods provide a systematic way to evaluate the performance of human-machine systems and identify areas for improvement.

In addition to the challenges related to the integration of multiple systems and the consideration of social and organizational factors, there are also ethical issues related to HSI in transportation (Council, 2007). For example, the development and deployment of autonomous vehicles raises ethical questions related to the responsibility for accidents and the impact of autonomous vehicles on employment and social inequality (Taeihagh & Lim, 2019). Researchers have also highlighted the importance of considering the ethical implications of HSI in transportation and developing guidelines for the development and deployment of new technologies (Aitsi-Selmi et al., 2016).

4. Human Systems Integration Applications in Healthcare:

To enhance the quality of healthcare delivery, HSI can be used to integrate human factors into healthcare processes, systems, and technologies. This article explores the applications of HSI in healthcare and examines recent research articles that highlight its potential in the healthcare sector (Carayon, 2006). HSI has several applications in the healthcare industry, including the following:

4.1 Design of Healthcare Technologies

Healthcare technologies, such as electronic health records (EHRs), medical devices, and telemedicine systems, are designed to improve patient care and safety. However, if these technologies are not designed with the needs of the end-users in mind, they can lead to adverse events and medical errors (Kwak, 2005). HSI can be used to design healthcare technologies that are user-friendly, safe, and effective. HSI considers the cognitive, physical, and emotional abilities of end-users to ensure that they can interact with the technology efficiently and effectively (Schulz et al., 2015).

4.2 Training and Education:

HSI can be used to enhance the training and education of healthcare professionals. Medical professionals require extensive training to acquire the necessary knowledge and skills to provide high-quality care (Svavarsdóttir et al., 2016). However, traditional training methods can be time-consuming, expensive, and may not provide sufficient hands-on experience (Svavarsdóttir et al., 2016). HSI can be used to design training programs that are more efficient, cost-effective, and provide realistic simulations of medical scenarios. HSI can also be used to develop educational materials that are accessible, easy to understand, and engaging (Jeffries, 2005).

4.3 Patient Safety:

Patient safety is a critical component of healthcare delivery. Medical errors, such as misdiagnosis, medication errors, and surgical errors, can have severe consequences for patients. HSI can be used to identify and mitigate risks that may lead to medical errors. HSI can also be used to design patient-centered care processes that improve communication between healthcare providers and patients, reduce wait times, and improve the overall patient experience (Ko et al., 2019).

4.4 Workflow and Process Design:
HSI can be used to optimize the workflow and processes in healthcare facilities. Healthcare facilities are complex systems that involve a range of processes, from patient registration to discharge (Arbaje et al., 2019). HSI can be used to identify areas where the processes may be inefficient or lead to delays. HSI can also be used to streamline processes, reduce wait times, and improve the overall patient experience (Alowad et al., 2021).

4.5 eHealth:
eHealth encompasses a broad range of technology and systems designed to support healthcare. (Dopp et al., 2020) conducted a literature review to explore the application of HSI and usability principles in eHealth, emphasizing the importance of user-centered design and understanding user needs to ensure that technology and systems are effective in supporting healthcare.

4.6 Mobile Health Applications:
Mobile health (mHealth) applications are becoming increasingly popular for managing chronic diseases. (Lazaro et al., 2022) highlight the importance of considering human factors and usability in mHealth application design. They argue that by applying HSI principles, mHealth applications can be designed to be more user-friendly, thus improving patient engagement and health outcomes.

5. Human Systems Integration Applications in Manufacturing:
Manufacturing is a complex and diverse industry that requires high levels of efficiency, safety, and quality. HSI can help address the challenges and opportunities of manufacturing by improving the usability, safety, and performance of manufacturing systems, equipment, and processes (Lu et al., 2022). Applications of HSI in Manufacturing include;

5.1 Equipment design and ergonomics:
HSI can improve the design and ergonomics of manufacturing equipment to reduce the risk of musculoskeletal disorders and injuries caused by repetitive motions, awkward postures, and forceful exertions. HSI can also improve the usability of equipment by considering the user's needs, capabilities, and limitations. For example, (Karwowski & Zhang, 2021) applied HSI to redesign the control panel of a food extrusion machine to improve the operator's performance, comfort, and safety.

5.2 Automation and human-robot collaboration:
HSI can help optimize the automation of manufacturing processes to increase productivity, quality, and safety. HSI can also support the collaboration between humans and robots to improve efficiency and reduce errors. (Lv et al., 2021) investigated the effects of human-robot collaboration on the productivity and safety of a manufacturing process and found that HSI can enhance the communication and coordination between human operators and robots.

5.3 Safety and risk management:
HSI can improve safety and risk management in manufacturing by identifying and mitigating hazards, reducing human errors, and ensuring compliance with safety regulations. HSI can also improve the safety culture of manufacturing organizations by promoting safety awareness, training, and reporting. For example, (Zhang et al., 2022) used HSI to develop a risk assessment framework for a manufacturing plant that considers the human, technological, and environmental factors that affect safety.

5.4 Process design and optimization:
HSI can help optimize the design and management of manufacturing processes to improve efficiency, quality, and sustainability. HSI can also reduce the cognitive workload and fatigue of operators by simplifying and standardizing tasks and procedures. For example, (Peng et al., 2021) applied HSI to redesign the assembly process of a small electronic device to improve the efficiency and quality of the process and reduce operator fatigue.

5.5 Training and education:
HSI can enhance the training and education of manufacturing workers by providing them with the knowledge, skills, and attitudes needed to use technology and systems effectively and safely. HSI can also support the continuous learning and improvement of manufacturing workers by providing them with feedback and opportunities for reflection and innovation. For example, (Adami et al., 2021) developed a training program that combines HSI with virtual reality technology to improve the performance and safety of operators of a welding robot.

5.6 Benefits of HSI in Manufacturing:

The application of HSI in manufacturing can have several benefits included in Table 1:

Table 1. Benefits of HSI in Manufacturing

	Benefits	Description
1	Improved usability and user experience	HSI can improve the usability and user experience of manufacturing systems, equipment, and processes by considering the user's needs, capabilities, and limitations. This can lead to better performance, satisfaction, and safety of the user (Irizarry et al., 2012).
2	Enhanced productivity and efficiency	HSI can enhance the productivity and efficiency of manufacturing processes by optimizing the interaction between humans, technology, and the environment. This can lead to faster cycle times, higher throughput, and lower costs (Rüßmann et al., 2015).
3	Reduced errors and rework	HSI can reduce errors and rework in manufacturing by identifying and mitigating the factors that contribute to human errors, such as fatigue, stress, and cognitive overload. This can lead to higher quality, lower waste, and lower costs (Bridges & Tew, 2010).
4	Improved safety and risk management	HSI can improve safety and risk management in manufacturing by identifying and mitigating hazards, reducing human errors, and ensuring compliance with safety regulations (Gander et al., 2011). This can lead to a safer working environment, fewer accidents and injuries, and lower insurance costs.
5	Enhanced innovation and creativity	HSI can enhance innovation and creativity in manufacturing by providing opportunities for reflection, experimentation, and collaboration (Romero & Molina, 2011). This can lead to new ideas, products, and services that meet the changing needs and preferences of customers.

5.7 Challenges of HSI in Manufacturing:

The application of HSI in manufacturing can also pose several challenges included in Table 2:

Table 2. Challenges of HSI in Manufacturing

	Challenges	Description
1	Cost and time constraints	HSI can require significant investments in research, development, and implementation, which can be challenging for small and medium-sized manufacturing companies (Stentoft et al., 2021). HSI can also require more time and resources for testing, evaluation, and feedback, which can delay the adoption of new technologies and processes.
2	Resistance to change	HSI can require changes in the culture, mindset, and skills of manufacturing workers and managers, which can lead to resistance, skepticism, and fear of job loss (Lambrechts et al., 2021). HSI can also require changes in the organizational structure, policies, and procedures, which can be challenging to implement (Lambrechts et al., 2021).
3	Complexity and uncertainty	HSI can involve complex and uncertain interactions between humans, technology, and the environment, which can pose challenges for modeling, analysis, and prediction (Fletcher et al., 2013). HSI can also involve ethical, legal, and social implications that require careful consideration and communication (Fletcher et al., 2013).
4	Interdisciplinary collaboration	HSI can require collaboration between multiple disciplines, such as psychology, engineering, design, and management, which can pose challenges for communication, coordination, and integration (Sonnenwald & Pierce, 2000). HSI can also require a shared language, methodology, and vision that can be challenging to establish (Sonnenwald & Pierce, 2000).

6. Human Systems Integration challenges and barriers:

Despite the potential benefits of HSI, implementing it in real-world settings can be challenging. In this article, we will review recent journal articles on the challenges of HSI, highlighting the key barriers and opportunities for addressing them (Sligo et al., 2017). The Barriers to HSI Implementation Include

6.1 Limited stakeholder involvement:

One of the main barriers to HSI implementation is the limited involvement of stakeholders, such as users, operators, designers, and managers. HSI requires a collaborative approach that involves understanding the needs and perspectives of different stakeholders and integrating them into the design and evaluation process (Pereno & Eriksson, 2020). However, stakeholders may have competing interests, limited time or resources, or lack of awareness of the HSI principles and methods (Reed et al., 2009). As a result, their input may be incomplete, inconsistent, or biased, which can lead to suboptimal system design and poor user acceptance. Some recent studies on stakeholder involvement and HSI include (Middleton et al., 2013), This study investigated the effects of user participation and functional fit on the usability of electronic health record systems. The authors conducted a survey of 270 healthcare professionals who used a newly implemented EHR system. The results showed that user participation and functional fit were positively related to the perceived usability of the system, indicating the importance of involving users in the design and evaluation of EHR systems. (Zhou et al., 2021) proposed a multi-stakeholder decision-making approach for enhancing the human-centered design of medical devices. The authors conducted a case study of a medical device design project, in which they involved users, designers, engineers, and managers in the decision-making process. The results showed that the approach led to better alignment of user needs and design requirements and improved the usability and user satisfaction of the device.

6.2 Complexity and variability of human factors:

Another barrier to HSI implementation is the complexity and variability of human factors. Human factors encompass a wide range of physical, cognitive, and emotional capabilities and limitations, which can vary across individuals, contexts, and time (Karwowski, 2006). HSI needs to account for these factors in the design and evaluation of systems, to ensure that they are compatible with the capabilities and limitations of the users (Bannon, 1995). However, the complexity and variability of human factors can make it difficult to identify and address all the relevant factors, and to balance the trade-offs between conflicting requirements (Pagell et al., 2015). Some recent studies on human factors and HSI include:

6.3 Lack of HSI expertise and knowledge

A third barrier to HSI implementation is the lack of HSI expertise and knowledge among designers, engineers, and managers. HSI requires a multidisciplinary approach that integrates knowledge and skills from different fields, such as human factors, ergonomics, psychology, engineering, and management. However, many professionals may not have sufficient training or awareness of HSI principles and methods, or may not have access to HSI resources or tools (Madni, 2010). As a result, they may overlook or underestimate the importance of HSI in system design and management, or may not be able to apply HSI effectively. Some recent studies on HSI expertise and knowledge include (Rodríguez et al., 2020), This study developed a human factors engineering training program for the railway industry, which aimed to enhance the HSI expertise and knowledge of engineers, designers, and managers. The authors conducted a needs assessment and curriculum development process and evaluated the program's effectiveness using pre- and post-training surveys. The results showed that the program led to significant improvements in HSI knowledge, skills, and attitudes, indicating the potential benefits of HSI training for enhancing system performance and safety.

7. Opportunities for Addressing HSI Challenges:

Despite the challenges of HSI implementation, there are also opportunities for addressing them and enhancing the benefits of HSI. Some of these opportunities include:

7.1 Integration of HSI into the system development lifecycle:

One way to address the challenges of HSI is to integrate HSI principles and methods into the system development lifecycle (SDLC). SDLC is a process that describes the stages involved in the development and maintenance of a system, from the initial concept to the retirement phase (Laato et al., 2022). By integrating HSI into SDLC, designers, engineers, and managers can consider human factors from the early stages of the design process, such as requirements analysis, conceptual design, and detailed design (Council, 2007). This can help to identify and address potential HSI issues before they become embedded in the system, which can save time, costs, and improve performance and safety. (Tzeng et al., 2008) described a case study of integrating HSI into the system development process of an automatic machine, which aimed to improve the safety and efficiency of the machine. The authors used a human-centered design approach that involved users, experts, and designers in the design process, and used various HSI methods and tools, such as task analysis, usability testing, and risk assessment. The results showed that the integration of HSI led to significant improvements in the user interface, task performance, and safety of the machine, indicating the potential benefits of HSI integration into SDLC.

7.2 Collaboration and communication among stakeholders

Another way to address the challenges of HSI is to promote collaboration and communication among stakeholders, such as designers, engineers, managers, users, and regulators. HSI requires a team-based approach that involves the participation and input of multiple stakeholders, who may have different perspectives, goals, and needs (Cooper et al., 2005). By promoting collaboration and communication, designers, engineers, and managers can share their knowledge, insights, and concerns about HSI, and can work together to address HSI issues and improve system performance and safety (Council, 2007). (Ismatullaev & Kim, 2022) described a case study of designing a clinical decision support system (CDSS) that involved collaboration and communication among different stakeholders, such as clinicians, patients, designers, and engineers. The authors used a participatory design approach that involved users in the design process, and used various HSI methods and tools, such as cognitive task analysis, heuristic evaluation, and usability testing. The results showed that the CDSS was well-received by users and led to significant improvements in clinical decision-making, indicating the potential benefits of collaboration and communication in HSI design.

7.3 Use of advanced technologies and methods

A third way to address the challenges of HSI is to use advanced technologies and methods that can support the integration of HSI principles and methods into system design and management. Some of these technologies and methods include virtual and augmented reality, artificial intelligence, machine learning, and big data analytics (Kirkley & Kirkley, 2005). These technologies and methods can help to simulate and predict human behavior and performance, identify and mitigate HSI risks, and optimize system design and management (Power & Sharda, 2007). (Harris et al., 2019) described a virtual patient model that was used to simulate clinical decision-making and to evaluate the impact of HSI factors on decision-making. The virtual patient model was developed using cognitive task analysis and other HSI methods and was based on real clinical cases. The results showed that the virtual patient model was effective in identifying HSI issues in clinical decision-making, and in predicting the impact of different interventions on decision-making performance, indicating the potential benefits of using advanced technologies and methods in HSI.

7.4 Integration of HSI into training and education:

A fourth way to address the challenges of HSI is to integrate HSI principles and methods into training and education programs for designers, engineers, and managers. By providing education and training on HSI, these professionals can develop the knowledge, skills, and attitudes necessary to integrate HSI into system design and management, and to address HSI issues throughout the system lifecycle (Council, 2007). This can help to promote a culture of safety and performance, and to reduce the risks and costs associated with HSI failures. (Gaba et al., 2001) described a simulation-based training program in anesthesia crisis resource management (ACRM) that integrated HSI principles and methods into the training curriculum. The training program was designed to improve the teamwork and communication skills of anesthesia providers, and to reduce the risk of adverse events during anesthesia procedures. The results showed that the simulation-based training program was effective in improving the performance of anesthesia providers, and in reducing the frequency and severity of adverse events, indicating the potential benefits of integrating HSI into training and education.

8. Conclusion:

Human Systems Integration (HSI) is a multidisciplinary field that aims to optimize the performance of human-machine systems by considering the characteristics and capabilities of both human operators and technological systems. The concept of HSI has its roots in the field of ergonomics, which focuses on the design of equipment and work environments to fit the physical and psychological characteristics of human operators. However, HSI has evolved to encompass a broader range of issues, including the integration of multiple systems, the management of information, and the development of interfaces that are intuitive and easy to use. HSI is of particular importance in the design and operation of complex systems such as aviation, transportation, medicine, and military operations. The field of HSI faces a number of challenges, such as the integration of multiple systems, the social and organizational factors that can impact the performance of human-machine systems, and the need to consider the cognitive and affective aspects of human operators in the design of systems. In order to address these challenges, researchers have developed methods for assessing the performance of human-machine systems, such as Situation Awareness Global Assessment Technique and the Human Factors Analysis and Classification System. As technology continues to advance and human-machine systems become increasingly complex, the importance of HSI will only continue to grow.

References

Adami, P., Rodrigues, P. B., Woods, P. J., Becerik-Gerber, B., Soibelman, L., Copur-Gencturk, Y., & Lucas, G. (2021). Effectiveness of VR-based training on improving construction workers' knowledge, skills, and safety behavior in robotic teleoperation. *Advanced Engineering Informatics*, *50*, 101431.

Ahmed, H. (2022). *HUMAN SYSTEMS INTEGRATION OF AGRICULTURAL MACHINERY IN DEVELOPING ECONOMY COUNTRIES: SUDAN AS A CASE STUDY* Colorado State University].

Ahmed, H., Miller, E., & Ahmed, M. (2023). Facts, Myths, and Evolving Research Agenda on the Mechanization of the African Agricultural Sector.

Ahmed, H., & Miller, E. E. (2022). Human-Systems Integration of Agricultural Machinery in Developing Economy Countries: Perceptions of Adoption. INCOSE International Symposium,

Aitsi-Selmi, A., Murray, V., Wannous, C., Dickinson, C., Johnston, D., Kawasaki, A., Stevance, A.-S., & Yeung, T. (2016). Reflections on a science and technology agenda for 21st century disaster risk reduction: Based on the scientific content of the 2016 UNISDR science and technology conference on the implementation of the Sendai framework for disaster risk reduction 2015–2030. *International Journal of Disaster Risk Science*, *7*, 1-29.

Al Hosani, N., Fathelrahman, E., Ahmed, H., & Rikab, E. (2022). Moving Bed Biofilm Reactor (MBBR) for decentralized grey water treatment: Technical, ecological and cost efficiency comparison for domestic applications. *Emirates Journal of Food and Agriculture*.

Alowad, A., Samaranayake, P., Ahsan, K., Alidrisi, H., & Karim, A. (2021). Enhancing patient flow in emergency department (ED) using lean strategies–an integrated voice of customer and voice of process perspective. *Business Process Management Journal*, *27*(1), 75-105.

Arbaje, A. I., Hughes, A., Werner, N., Carl, K., Hohl, D., Jones, K., Bowles, K. H., Chan, K., Leff, B., & Gurses, A. P. (2019). Information management goals and process failures during home visits for middle-aged and older adults receiving skilled home healthcare services after hospital discharge: a multisite, qualitative study. *BMJ quality & safety*, *28*(2), 111-120.

Bannon, L. J. (1995). From human factors to human actors: The role of psychology and human-computer interaction studies in system design. In *Readings in human–computer interaction* (pp. 205-214). Elsevier.

Bensing, J. (2000). Bridging the gap.: The separate worlds of evidence-based medicine and patient-centered medicine. *Patient education and counseling*, *39*(1), 17-25.

Blomberg, O. (2011). Conceptions of cognition for cognitive engineering. *The international journal of aviation psychology*, *21*(1), 85-104.

Booher, H. R. (2003). *Handbook of human systems integration* (Vol. 23). John Wiley & Sons.

Boy, G. A. (2020). *Human–systems integration: from virtual to tangible*. CRC Press.

Bridges, W., & Tew, R. (2010). Human factors elements missing from process safety management (PSM). 6th global congress on process safety and 44th annual loss prevention symposium, San Antonio, Texas,

Carayon, P. (2006). Human factors of complex sociotechnical systems. *Applied ergonomics*, *37*(4), 525-535.

Cooper, D. F., Grey, S., Raymond, G., & Walker, P. (2005). *Project risk management guidelines*. Wiley.

Council, N. R. (2007). *Human-system integration in the system development process: A new look*. National Academies Press.

Cunningham, M., & Regan, M. A. (2015). Autonomous vehicles: human factors issues and future research. Proceedings of the 2015 Australasian Road safety conference,

Curcuruto, M., Griffin, M. A., Kandola, R., & Morgan, J. I. (2018). Multilevel safety climate in the UK rail industry: A cross validation of the Zohar and Luria MSC scale. *Safety science*, *110*, 183-194.

Davidse, R. J. (2006). Older drivers and ADAS: Which systems improve road safety? *IATSS research*, *30*(1), 6-20.

Denyer, D., Tranfield, D., & Van Aken, J. E. (2008). Developing design propositions through research synthesis. *Organization studies*, *29*(3), 393-413.

Dopp, A. R., Parisi, K. E., Munson, S. A., & Lyon, A. R. (2020). Aligning implementation and user-centered design strategies to enhance the impact of health services: results from a concept mapping study. *Implementation Science Communications*, *1*(1), 1-13.

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. Proceedings of the Human Factors Society annual meeting,

Fletcher, T. D., Andrieu, H., & Hamel, P. (2013). Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art. *Advances in water resources*, *51*, 261-279.

Forlizzi, J., Barley, W. C., & Seder, T. (2010). Where should i turn: moving from individual to collaborative navigation strategies to inform the interaction design of future navigation systems. Proceedings of the SIGCHI conference on human factors in computing systems,

Gaba, D. M., Howard, S. K., Fish, K. J., Smith, B. E., & Sowb, Y. A. (2001). Simulation-based training in anesthesia crisis resource management (ACRM): a decade of experience. *Simulation & gaming*, *32*(2), 175-193.

Gander, P., Hartley, L., Powell, D., Cabon, P., Hitchcock, E., Mills, A., & Popkin, S. (2011). Fatigue risk management: Organizational factors at the regulatory and industry/company level. *Accident Analysis & Prevention*, *43*(2), 573-590.

Guériau, M., Billot, R., El Faouzi, N.-E., Monteil, J., Armetta, F., & Hassas, S. (2016). How to assess the benefits of connected vehicles? A simulation framework for the design of cooperative traffic management strategies. *Transportation research part C: emerging technologies*, *67*, 266-279.

Harris, P. A., Taylor, R., Minor, B. L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., & Kirby, J. (2019). The REDCap consortium: building an international community of software platform partners. *Journal of biomedical informatics*, *95*, 103208.
Helander, M. (1997). Forty years of IEA: some reflections on the evolution of ergonomics. *Ergonomics*, *40*(10), 952-961.
Helander, M. G. (2014). *Handbook of human-computer interaction*. Elsevier.
Irizarry, J., Gheisari, M., & Walker, B. N. (2012). Usability assessment of drone technology as safety inspection tools. *Journal of Information Technology in Construction (ITcon)*, *17*(12), 194-212.
Ismatullaev, U. V. U., & Kim, S.-H. (2022). Review of the Factors Affecting Acceptance of AI-Infused Systems. *Human Factors*, 00187208211064707.
Issa, T., & Isaias, P. (2022). Usability and Human–Computer Interaction (HCI). In *Sustainable Design: HCI, Usability and Environmental Concerns* (pp. 23-40). Springer.
Jeffries, P. R. (2005). A framework for designing, implementing, and evaluating: Simulations used as teaching strategies in nursing. *Nursing education perspectives*, *26*(2), 96-103.
Kaber, D. B., Onal, E., & Endsley, M. R. (2000). Design of automation for telerobots and the effect on performance, operator situation awareness, and subjective workload. *Human factors and ergonomics in manufacturing & service industries*, *10*(4), 409-430.
Karwowski, W. (2006). The discipline of ergonomics and human factors. *Handbook of human factors and ergonomics*, 1-31.
Karwowski, W., & Zhang, W. (2021). The discipline of human factors and ergonomics. *Handbook of human factors and ergonomics*, 1-37.
Kirkley, S. E., & Kirkley, J. R. (2005). Creating next generation blended learning environments using mixed reality, video games and simulations. *TechTrends*, *49*(3), 42-53.
Ko, D. G., Mai, F., Shan, Z., & Zhang, D. (2019). Operational efficiency and patient-centered health care: A view from online physician reviews. *Journal of Operations Management*, *65*(4), 353-379.
Kwak, Y. S. (2005). International standards for building electronic health record (ehr). Proceedings of 7th International Workshop on Enterprise networking and Computing in Healthcare Industry, 2005. HEALTHCOM 2005.,
Laato, S., Mäntymäki, M., Minkkinen, M., Birkstedt, T., Islam, A., & Dennehy, D. (2022). Integrating machine learning with software development lifecycles: Insights from experts.
Lambrechts, W., Klaver, J. S., Koudijzer, L., & Semeijn, J. (2021). Human factors influencing the implementation of Cobots in high volume distribution centres. *Logistics*, *5*(2), 32.
Lazaro, M. J., Alvaran, A., Yun, M. H., & Kim, S. (2022). Mobile health application for seizure management: A human-systems integration approach. *Human Factors*, 00187208221074427.
Lu, Y., Zheng, H., Chand, S., Xia, W., Liu, Z., Xu, X., Wang, L., Qin, Z., & Bao, J. (2022). Outlook on human-centric manufacturing towards Industry 5.0. *Journal of Manufacturing Systems*, *62*, 612-627.
Lv, Q., Zhang, R., Sun, X., Lu, Y., & Bao, J. (2021). A digital twin-driven human-robot collaborative assembly approach in the wake of COVID-19. *Journal of Manufacturing Systems*, *60*, 837-851.
Lyu, N., Deng, C., Xie, L., Wu, C., & Duan, Z. (2019). A field operational test in China: Exploring the effect of an advanced driver assistance system on driving performance and braking behavior. *Transportation research part F: traffic psychology and behaviour*, *65*, 730-747.
Madni, A. M. (2010). Integrating humans with software and systems: Technical challenges and a research agenda. *Systems Engineering*, *13*(3), 232-245.
Martínez-Caro, E., Cegarra-Navarro, J. G., & Alfonso-Ruiz, F. J. (2020). Digital technologies and firm performance: The role of digital organisational culture. *Technological Forecasting and Social Change*, *154*, 119962.
Middleton, B., Bloomrosen, M., Dente, M. A., Hashmat, B., Koppel, R., Overhage, J. M., Payne, T. H., Rosenbloom, S. T., Weaver, C., & Zhang, J. (2013). Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA. *Journal of the American Medical Informatics Association*, *20*(e1), e2-e8.
Miller, G. (1999). Human Factors Engineering (HFE): What it is and how it can be used to reduce human errors in the offshore industry. Offshore Technology Conference,
Möller, D. P., Haas, R. E., Möller, D. P., & Haas, R. E. (2019). Advanced driver assistance systems and autonomous driving. *Guide to Automotive Connectivity and Cybersecurity: Trends, Technologies, Innovations and Applications*, 513-580.
Morrissett, A., Eini, R., Zaman, M., Zohrabi, N., & Abdelwahed, S. (2019). A physical testbed for intelligent transportation systems. 2019 12th International Conference on Human System Interaction (HSI),
Pagell, M., Klassen, R., Johnston, D., Shevchenko, A., & Sharma, S. (2015). Are safety and operational effectiveness contradictory requirements: The roles of routines and relational coordination. *Journal of*

Operations Management, *36*, 1-14.

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2008). Situation awareness, mental workload, and trust in automation: Viable, empirically supported cognitive engineering constructs. *Journal of cognitive engineering and decision making*, *2*(2), 140-160.

Patel, V. L., Kaufman, D. R., & Arocha, J. F. (2002). Emerging paradigms of cognition in medical decision-making. *Journal of biomedical informatics*, *35*(1), 52-75.

Peng, X., Kong, L., Fuh, J. Y. H., & Wang, H. (2021). A review of post-processing technologies in additive manufacturing. *Journal of Manufacturing and Materials Processing*, *5*(2), 38.

Pereno, A., & Eriksson, D. (2020). A multi-stakeholder perspective on sustainable healthcare: From 2030 onwards. *Futures*, *122*, 102605.

Pickering, C. A., Bumnham, K. J., & Richardson, M. J. (2007). A review of automotive human machine interface technologies and techniques to reduce driver distraction. 2007 2nd Institution of Engineering and Technology International Conference on System Safety,

Power, D. J., & Sharda, R. (2007). Model-driven decision support systems: Concepts and research directions. *Decision support systems*, *43*(3), 1044-1061.

Rautaray, S. S., & Agrawal, A. (2012). Real time multiple hand gesture recognition system for human computer interaction. *International Journal of Intelligent Systems and Applications*, *4*(5), 56-64.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. H., & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of environmental management*, *90*(5), 1933-1949.

Rodríguez, A. A., Escanilla, D. E., Caroca, L. A., Albornoz, C. E., Marshall, P. A., Molenbroek, J. F., & Castellucci, H. I. (2020). Level of match between facial dimensions of Chilean workers and respirator fit test panels proposed by LANL and NIOSH. *International Journal of Industrial Ergonomics*, *80*, 103015.

Romero, D., & Molina, A. (2011). Collaborative networked organisations and customer communities: value co-creation and co-innovation in the networking era. *Production Planning & Control*, *22*(5-6), 447-472.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston consulting group*, *9*(1), 54-89.

Schulz, R., Wahl, H.-W., Matthews, J. T., De Vito Dabbs, A., Beach, S. R., & Czaja, S. J. (2015). Advancing the aging and technology agenda in gerontology. *The gerontologist*, *55*(5), 724-734.

Sharma, R. P., & Verma, G. K. (2015). Human computer interaction using hand gesture. *Procedia Computer Science*, *54*, 721-727.

Sligo, J., Gauld, R., Roberts, V., & Villa, L. (2017). A literature review for large-scale health information system project planning, implementation and evaluation. *International journal of medical informatics*, *97*, 86-97.

Sonnenwald, D. H., & Pierce, L. G. (2000). Information behavior in dynamic group work contexts: interwoven situational awareness, dense social networks and contested collaboration in command and control. *Information Processing & Management*, *36*(3), 461-479.

Stanton, N. A., & Salmon, P. M. (2009). Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems. *Safety science*, *47*(2), 227-237.

Stentoft, J., Adsbøll Wickstrøm, K., Philipsen, K., & Haug, A. (2021). Drivers and barriers for Industry 4.0 readiness and practice: empirical evidence from small and medium-sized manufacturers. *Production Planning & Control*, *32*(10), 811-828.

Stonebraker, M., & Hellerstein, J. M. (2001). Content integration for e-business. Proceedings of the 2001 ACM SIGMOD international conference on Management of data,

Svavarsdóttir, M. H., Sigurðardóttir, Á. K., & Steinsbekk, A. (2016). Knowledge and skills needed for patient education for individuals with coronary heart disease: The perspective of health professionals. *European Journal of Cardiovascular Nursing*, *15*(1), 55-63.

Taeihagh, A., & Lim, H. S. M. (2019). Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport reviews*, *39*(1), 103-128.

Tzeng, S.-F., Chen, W.-H., & Pai, F.-Y. (2008). Evaluating the business value of RFID: Evidence from five case studies. *International journal of production economics*, *112*(2), 601-613.

Vicente, K. J., & Rasmussen, J. (1990). The ecology of human-machine systems II: Mediating'direct perception'in complex work domains. *Ecological psychology*, *2*(3), 207-249.

Wiener, E. L., & Nagel, D. C. (1988). *Human factors in aviation*. Gulf Professional Publishing.

Zhang, P., Liu, Q., Wang, Y., Zhu, D. Z., Liang, R., Qin, L., Li, R., Ji, Q., & Li, K. (2022). River habitat assessment and restoration in high dam flood discharge systems with total dissolved gas supersaturation. *Water Research*, *221*, 118833.

Zhou, F., Ji, Y., & Jiao, R. J. (2021). Emotional design. *Handbook of human factors and ergonomics*, 236-251.