CHAPTER 15

Ergonomics and Human Factors for a Sustainable Future: Suggestions for a Way Forward

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Introduction

In this book we have looked at the ways in which human factors and ergonomics (HFE) can contribute to a more sustainable future. As Nickerson (1992) noted, in essence the HFE aim with regard to sustainability can be summarised as facilitating behaviour change. This can be achieved through using a number of HFE strategies including design using behaviour-shaping constraints (Vicente, 1998), the design of feedback mechanisms or the provision of information (Drury, 2008, 2014; Martin, Legg, & Brown, 2013; Vicente, 1998), and the design of decision-support systems (Drury, 2008, 2014). More specifically, the suggestions for the domains where HFE can contribute to sustainability are through designing for reduced/durable/recycled resource use (Hanson, 2013; Thatcher, 2013),

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A. Thatcher, P. H. P. Yeow (eds.), *Ergonomics and Human Factors for a Sustainable Future*, https://doi.org/10.1007/978-981-10-8072-2_15

the design of jobs to support work within the green economy (Hanson, 2013; Thatcher, 2013), the design to support corporate sustainability (Steimle & Zink, 2006; Zink, Steimle, & Fischer, 2008), and the design of disaster management services (Hanson, 2013; Moore & Barnard, 2012).

Numerous authors have identified a range of different places where HFE interventions would be most relevant. This list is extensive and can only be summarised here. Within the domain of design for reduced/durable/recycled resource use are products and systems that include the efficient use of energy, water, food, land, materials, transportation, and cities, and the reduction of various types of waste (Hanson, 2013; Martin et al., 2013; Moray, 1995; Nickerson, 1992; Radjiyev, Qiu, Xiong, & Nam 2015; Thatcher, 2013). In the domain of job design, the emphasis is on ensuring wellbeing, health, and safety (see Docherty, Forslin, & Shani, 2002) across a wide array of sectors including recycling, renewable energy installations, organic farming, and work in extreme climatic environments (Hanson, 2013). The corporate sustainability domain overlaps partially with the job design domain with suggestions for improving health and safety as well as wellbeing. However, suggestions in this domain also include designing appropriate corporate social responsibility initiatives, considering the design of organisations across geographical space, and ensuring sustainable economic success (Steimle & Zink, 2006; Zink, 2014; Zink, Steimle, & Fischer, 2008). Suggested work in the disaster management domain includes designing appropriate security systems to prevent violence and terrorism (Moray, 1995), healthcare and emergency services to cope with natural and humanitarian disasters (Moore & Barnard, 2012; Steimle & Zink, 2006), and the design of other complex systems to avert disasters (Steimle & Zink, 2006).

Drury (2014) emphasises that HFE's role might play out at four levels. At the most basic level, HFE should be involved with trying to assist behaviour change at the personal level, regardless of the context (i.e. at home, at work, at play, etc.). HFE interventions that occur at this level are primarily about changing consumption, waste reduction, and lifestyle choices and behaviours. At the next level, HFE should be involved in behaviour change at the work level. This would involve influencing groups to change behaviours to reduce waste and optimise the efficient use of resources. At the third level, HFE should be involved with changing behaviour at the general public level. For Drury (2014), behaviour change at this level would primarily be through designing feedback systems to optimise efficient use of resources. At the broadest level, HFE should be involved with design of systems to support decision-making behaviour at the government or policy level.

Having considered the great potential that HFE has for contributing solutions to these sustainability challenges and having reviewed what we has already been conducted, we now turn our attention to what we consider to be the future goals for our discipline. Since this book is about HFE's role in enabling a sustainable future, we express these goals in terms of where we are now ("from") and what skills and ideas we still need to develop ("to"). We have identified five goals that we believe emerge naturally from the work presented in this book. These themes are (1) from specialised, to multidisciplinary, to transdisciplinary; (2) from systems HFE to complexity HFE; (3) from positivism to value-laden science; (4) from mitigation to adaptation; and (5) from general to local solutions. We acknowledge that these goals are strongly influenced by Moray's (1995) assessment of what our discipline needs to do to meet the global challenges facing humanity published more than 20 years ago. We discuss each of these goals in more detail in the following sections.

Goal 1: From Specialised to Multidisciplinary, Interdisciplinary, and Transdisciplinary

As we mentioned in Chap. 1, one of the features of this book is the wide range of disciplines that have contributed to compiling this collection. As Moray (1995) noted, the problems that emerge from sustainability require expert input from many different disciplinary perspectives. The HFE discipline itself is naturally adept at drawing knowledge and expertise from many different disciplines including an understanding of physiology, anatomy, biomechanics, psychology, sociotechnical systems, and design theory. However, with the challenges that emerge from sustainability, it will be necessary to engage more broadly with the social sciences such as sociology, political science, anthropology, philosophy, human resources, and the management sciences. Chapters 2, 3, 4, 8, 11, 12 and 13 do this to some extent. Also, given the damage that we are currently inflicting on our natural environment, it will also be necessary to engage with the ecological and biological sciences. The work contained in Thatcher and Yeow (2016) and in Richardson et al. (2017) goes some way to making connections between HFE and the ecological sciences. This work is also included in Chaps. 2 and 7 of this book.

This is not the first time that the necessity for diverse disciplinarity within HFE has been raised. Wisner (1985) called for more engagement between HFE and anthropology; Moray (2000) called for greater connections between HFE, anthropology, and politics; Boudeau, Wilkin, and Dekker (2014) called for greater engagement between ergonomics and politics, while Wilkin (2010) called for a closer look at the philosophy of HFE. We are sure that these types of debates and discussions will make many people within the HFE discipline feel decidedly uncomfortable. For some, the discomfort is felt because these proposals call for people within the HFE discipline to further share and dilute their specialised expertise. For others, these proposals may feel as if the HFE discipline is spreading itself too thin. Following Wilson (2014) we would argue that it is our understanding of systems that include humans that makes the HFE discipline distinct. But in order to meet this self-appointed mandate in the context of sustainability challenges means, we will also need to understand how the human systems interact in ever-larger groupings (e.g. at sociological, anthropological, and political levels). In addition, sustainability means understanding something about how ecological systems function and how our behaviour and interactions with these life-supporting systems can support or destroy them.

However, Lang et al. (2012) and Stokols, Misra, Runnerstrom, and Hipp (2009) have argued that the challenges presented by sustainability require disciplines to move beyond a multidisciplinary approach towards an interdisciplinary approach, or even a transdisciplinary approach. An interdisciplinary approach involves a level of cooperation in order to achieve a synthesis between different theories and methods. A transdisciplinary approach requires not just cooperation and synthesis but an integration of disciplinary knowledge and methods to create new, unified theoretical frameworks not limited by their original disciplinary stances. Fiore, Phillips, and Sellers (2014) have given a useful overview of transdisciplinary research and the central role such an approach might play in integrating the HFE discipline with other disciplines attempting to address sustainability challenges. In particular, it could be argued that the HFE discipline might contribute a unique blend of knowledge related to design, human physiology, human anatomy, and human behaviour and other aspects of human psychology.

There are very few published studies that demonstrate the types of roles that an HFE practitioner can play in assisting transdisciplinary teams to address sustainability challenges. One such example is the work of Moore and Barnard (2012). In this work they report on the role of the HFE practitioner in supporting the activities of the Sustainable Livelihoods Framework that also involved specialists from social anthropology, economics, planning, physical sciences, and representatives of community. The underlying goals of the project were to ensure that the deeply impoverished communities in the study area could develop sufficient social, natural, economic, and cultural capital to survive and thrive into the future (Moore & Barnard, 2012). As Moore and Barnard (2012) concluded, the role of the HFE specialist in this transdisciplinary team was to "build [an] understanding about the characteristics of people, including not only their physical and cognitive capabilities and limitations, but also the unique sets of aspirations, knowledge, and skills that they have reason to value" (p. 948). It should also be acknowledged that this understanding could not be achieved without also understanding something about the ecological, financial, and political constraints encountered by these communities.

In this book there are several chapters that extend on the interdisciplinary and transdisciplinary perspective of HFE. From a transdisciplinary perspective, there are a number of chapters that attempt to create new theoretical and methodological approaches through the integration across disciplines. Chapter 2 integrates ecological science theories with HFE theories. Chapter 3 integrates human resources and corporate social responsibility theories with HFE theories. Chapter 4 integrates marketing, information systems, and environmental science theories with HFE theories. Chapter 10 integrates management science theories with HFE theories. From an interdisciplinary perspective, Chap. 11 attempts to merge economics with environmental science and green ergonomics, while Chap. 13 looks at how political science theories can be used to address HFE issues. We would argue that this is a good start, but more work needs to be done in this area.

Goal 2: From Systems HFE to Complexity HFE

Several authors have noted that HFE is a systems discipline (Carayon, 2006; Dul et al., 2012; Wilson, 2014; Zink, 2014). The systems that the HFE discipline is interested in understanding are those that include humans and traditionally have spanned several levels of complexity from "simple" human-tool or human-task systems to more complex sociotechnical systems. However, as Siemieniuch, Sinclair, and Henshaw (2015) have observed, an even deeper understanding of complex systems is required to address the sustainability challenges. The theoretical models that have been developed within the HFE discipline so far each draw our attention to the need to embrace an understanding of complex systems (García-Acosta, Pinilla, Larrahondo, & Morales, 2014; Steimle & Zink, 2006; Thatcher, 2013; Thatcher & Yeow, 2016; Zink, 2014). Dekker, Hancock, and Wilkin (2013) went further by specifically outlining the qualities of complexity that require our understanding. These qualities include the need to understand local relationships, dynamic interactions, fuzzy boundaries, and emergent properties (Dekker et al., 2013). A detailed discussion of each of these concepts is beyond the scope of this chapter, but interested readers may wish to start with Dekker et al. (2013) and continue their reading with Cilliers (1998) and Norberg and Cumming (2008).

Each of the chapters in this book addresses the issue of complexity within systems in some way. We don't go through all the chapters in detail here but instead highlight a few examples. Chapter 2 tackles the issue of complexity in HFE systems-of-systems through trying to find ways to navigate through complex networks of interacting HFE systems. Chapter 3 demonstrates that understanding the relatively simple concept of "decent work" requires an understanding of the more complex issues of global supply chains, child labour, slave labour, and organisational ethics. Chapter 10 examines the issue of global supply chains more closely and the implications that this has for how we model work systems, by looking at the interrelated impacts of outsourcing and digitisation and how this complicates our understanding of the global production of work. Chapter 11 looks at the complex socio-ecological relationships associated with keeping a river clean. In this chapter, the authors consider how HFE might be used to understand and support the interrelationships between the various stakeholders that use a fresh water source, including the organisations that use water for production, the farmers who use water for agriculture, the communities that draw water for cleaning and consumption, and the government agency that regulate water use.

In support of what Zink and Fischer suggest in Chap. 10, we believe it will be necessary for complex systems theory to be introduced into the curricula of HFE educational programmes if the HFE discipline is going to make a difference to sustainability problems. The complexity that requires the attention from HFE stretches across time (such as product lifecycle ergonomics (Zink, 2014) or the sustainable system-of-systems perspective (Thatcher & Yeow, 2016)) and place (such as supply chain ergonomics (Hasle & Jensen, 2012)). Walker et al. (2010) make several cogent arguments as to why complex systems thinking should be an important factor to considering understanding HFE systems, not least would be because humans are the source of much of the complexity (Bar-Yam, 2002). However, Salmon, Walker, Read, Goode, and Stanton (2017) have questioned whether HFE has the existing evaluation tools to deal with this level of complexity. Currently our way of modelling HFE issues in complex systems is based on accident analysis methods such as Accimap (Rasmussen, 1997), the Systems Theoretic Accident Model and Process (STAMP) (Leveson, 2004), and the Human Factors Analysis and Classification System (HFACS) (Shappell & Wiegmann, 2012), or systems analysis methods such as Event Analysis of Systemic Teamwork (EAST) (Walker et al., 2006), the Functional Resonance Analysis Method (FRAM (Hollnagel, 2012), or Cognitive Work Analysis (CWA) (Vicente, 1999). However, these methods typically assess individuals and teams as the unit of analysis, rather than entire hierarchies of systems. One recent method to emerge is the Cognitive Work Analysis Design Toolkit (CWA-DT). The CWA-DT combines the traditional CWA approach with a participatory approach (Read, Salmon, Lenné, & Jenkins, 2015). This method shows promise because it has a transdisciplinary focus. While these methods may be useful for modelling sociotechnical systems, sustainability issues actually require the modelling of socio-ecological-technological systems. Further developments are therefore clearly required to integrate complexity thinking with HFE.

Goal 3: From Value-Free to Value-Laden Science

Wilkin (2010) argued that HFE likes to think of itself as an objective science that is, by implication, value-free. In this value-free conceptualisation, HFE sees itself as a discipline where "reliable knowledge is based on facts about the world that can be measured and verified through observation" (Wilkin, 2010, p. 234). However, this way of thinking within HFE assumes that interactions and behaviour take place within a closed system that is largely predictable. Arguably, very few HFE systems can truly be described as closed systems. As was shown in Chap. 2, in HFE the biological system (i.e. the human) interacts with social systems, embraced within various levels of political systems, financial systems, and ecological systems. While behaviour relevant for HFE may be measurable and observable at a localised micro level in a laboratory, HFE outcomes are far more difficult to reliably predict in the field. An example of how values are important in making informed decisions with more sustainable outcomes is to consider the case of alternative vehicle fuels. One of the options as an alternative energy source to fossil fuels in the vehicle industry is biofuels. It can be shown scientifically, both in a laboratory and in field testing, that biofuelled vehicles emit fewer greenhouse gases than fossil-fuelled vehicles (Pacala & Socolow, 2004). At face-value then, there may be important local health and wellbeing benefits for urban populations where these vehicles operate. However, a value-laden approach invites us to consider the values of the entire system, not just the scientific benefits of biofuels over fossil fuels. There are now numerous studies that suggest that there may be significant negative effects for human health and wellbeing from changing land use (Fargione, Hill, Tilman, Polasky, & Hawthorne, 2008). In particular, land that was previously being used to plant crops to feed people was being used to plant crops that were harvested for biofuels, causing food availability crises in some regions and rising food prices globally. Even more concerning, was the clearing of additional land (usually forested) to reap the benefits of additional income from biofuels. Clearing efforts have significantly increased the amount of carbon in the atmosphere through burning and by removing the carbon sinks such as trees (Fargione et al., 2008). In addition, Melillo et al. (2009) have noted that biofuel production results in increased greenhouse gas emissions from nitrous oxide due to increased fertilizer used to stimulate biofuel crop growth. The net effect of moving to biofuels is therefore likely to be reduced human health and wellbeing over a far greater area. The need for HFE to embrace this complexity has already been addressed in Goal 2 above. What is important to note from Wilkin's (2010) argument is that the predominant paradigm within HFE is that it assumes that it is value-free, but it is in fact a discipline that is actually value-laden, but that the values are not actually specified.

What values should HFE choose? Wilkin (2010) argues that the studies HFE chooses to conduct, the funding HFE chooses to seek, and the industries that support HFE initiatives all determine the values of the discipline. For Hancock and Drury (2011), HFE research and practice primarily aims to address the quality of life for the people who were the specified subject of HFE investigations. Here, the benefit is for the people funding the investigations and the relatively few direct recipients of those investigations. In addition, the values that drive this exercise are largely those of financial stability and the quality of work-life of a few. In particular, Hancock and Drury (2011) noted that the primary funders of HFE work (at least in the USA) were the military and large corporations. In fact, Moray (1995) referred to this traditional HFE role as supporting the "world of western liberal capitalism" (p. 1691), by which he meant the goal of HFE was to make the workplace more tolerable and effective/productive for workers in industrialised economies. These observations suggest that HFE already has an unstated set of values and that they benefit the few, rather than the many. Moray (1995) argued that the HFE discipline needs a clearly articulated (and presumably also an actively debated) set of values to guide the questions we should ask and the solutions that we seek.

What would these values look like? Dekker et al. (2013) considered values for the HFE discipline specifically for sustainability concerns. The values that Dekker et al. (2013) identified for HFE in a sustainability context were embracing complexity and emergence (i.e. Goal 2 as articulated here). More specifically, embracing complexity referred to a need to understand how local interactions have global consequences and to understand how interactions change over time. Embracing emergence meant anticipating that there could be unforeseeable consequences. Dekker et al. (2013) concluded that there should be further discussion about the appropriate values for HFE in the context of sustainability challenges. The only study that has clearly set out to define values for the HFE discipline is Lange-Morales, Thatcher, and García-Acosta (2014). Lange-Morales et al. (2014) accepted this challenge and developed a set of six values for HFE. These values are (1) respect for human rights, (2) respect for the Earth, (3) appreciation of complexity, (4) respect for diversity, (5) respect for transparency and openness, and (6) respect for ethical decision-making. Appreciation of complexity is also noted as Goal 2, and respect for diversity is partly captured by Goal 1 and Goal 5 in this chapter. There is yet to be a robust debate as to whether these are appropriate values for the HFE discipline. In this chapter we have already discussed the need to deepen our understanding of complexity. Next we will discuss the need to respect diversity.

Goal 4: From Mitigation to Adaptation

Incropera (2016) recommended two concurrent paths towards addressing sustainability challenges: mitigation and adaptation. The first path of mitigation involves reducing the rate of resource consumption per person to levels that are ecologically sustainable. This involves thinking about how our behaviour, products, and systems might be modified to reduce our current rate of impact on limited resources. From a human factors and ergonomics (HFE) perspective, this means designing products and systems that are more efficient and effective in utilising non-renewable resources or by finding ways to change our behaviour to adopt renewable resources or to reduce wastage of resource. Most of the examples presented and reviewed in this book portray various attempts at mitigation (i.e. reducing our current impact to forestall the chances of disaster in the future). Chapters 4, 5, 6, 9, 11, 12 and 13 each give examples of HFE work that addresses mitigation approaches. There are now numerous HFE examples of empirical work looking at interface design to ensure efficient use of resources (Durugbo, 2013; Fang & Sun, 2016; Harvey, Thorpe, & Fairchild, 2013; Katzeff, Nyblom, Tunheden, & Torstensson, 2012; Kobus et al., 2013; Revell & Stanton, 2016; Sauer, Wiese, & Rüttinger, 2002, 2003, 2004), design to understand and encourage the sustainable use of sustainable products (Cocron et al., 2013; Franke, Arend, McIlroy, & Stanton, 2016; Fréjus & Guibourdenche, 2012; Lee & Kang, 2013; Stanton et al., 2013; Stedmon, Winslow, & Langley, 2013; Young, Birrell, & Stanton, 2011), and the integration of employee wellbeing and effectiveness with sustainability initiatives (Bolis, Brunoro, & Sznelwar, 2016; Thatcher & Milner, 2014).

However, at the current rate of world population growth (Van den Bergh & Rietveld, 2004), it is likely that mitigation will be insufficient to stave off future disaster. Radical changes are required in human behaviour, possibly involving population control, to prevent the collapse of human-supporting ecosystems. In the absence of such radical behaviour changes, the second concurrent path that is required is adaptation. This means creating resilient products and systems that will be able to cope with the inevitable changes to the planet's ecosystems. Of special interest to HFE are products and systems that will allow humans to adapt to these changes. Some of these changes have already started to occur and therefore a concurrent strategy is already required. This book does not consider the adaptation requirements in any depth. Climate change is going to result in significant changes to the environments in which people need to perform work. For example, rising temperatures in most parts of the world will affect the physical wellbeing of people who need to perform physical work tasks (Kjellstrom, Gabrysch, Lemke, & Dear, 2009). This means an HFE examination of the tasks that can be performed or the design of tools and equipment that will allow the tasks to be performed under the modified conditions. Rising sea levels, for those people living near the sea, will affect where people live, the work that they will be able to perform, and the interconnections with other people (either moving people closer together if land becomes scarce, or separating people if islands start to form). Changing rainfall patterns and temperatures will affect which crops can be grown and which livestock can be farmed, significantly impacting on farming and food availability. What is needed is resilient socio-ecological-technical systems.

Goal 5: From General to Local Solutions

Using biological systems as a basis, Fiksel (2003) identified a number of key properties that could be transferred to the design of engineered systems to make them more resilient. Key among these properties is diversity. For Fiksel (2003) diversity refers to whether the (engineered) system contains multiple forms or allows for multiple behaviours. More forms and behaviours give the system a greater chance to recover from unusual disturbances and hence support sustainability. Lange-Morales et al. (2014) incorporated respect for diversity as one of the core values of HFE for sustainability. Diversity within the HFE discipline is often operationalised as cross-cultural design, but Lange-Morales et al. (2014) have suggested that we need to go further and understand the diversity of place (i.e. the geographical and cultural setting) and ecological diversity (i.e. our interactions with other biological entities). As a consequence of global variability, Moray (1995) argued that few HFE solutions are truly universal.

Lange-Morales et al. (2014) suggested that one of the ways to respect diversity and to foster variability is to encourage local HFE solutions for local HFE problems. Not only does this increase diversity but it is also a way of distributing and building HFE expertise and providing local employment. In addition, these types of indigenous HFE solutions are more likely to be accepted by local users as is commonly found in participatory HFE approaches (Imada, 1991; Martin et al., 2013). People who have to live and work with the consequences of HFE interventions are more likely to accept those interventions if they feel some ownership of the intervention or the evaluation process. Wisner's (1985) anthropotechnology approach takes a similar stance, warning of the dangers of simply transferring technology globally without due consideration of the cross-cultural, anthropological, geographical, and managerial implications.

There are now numerous parts of the world where a combination of colonial work practices and ill-considered technology transfers have left a complex array of working environments that seldom take due consideration of indigenous systems or cultures. In addition, since a large proportion of work worldwide actually takes place in the informal economy (Benjamin, Beegle, Recanatini, & Santini, 2014) where traditional HFE approaches seldom reach, HFE needs to re-think how it is to grow and make a difference. Moving from global to local solutions is an important way to bridge this gap.

Conclusions

In Chap. 1, we laid out the case for sustainability. In that discussion we demonstrated how humans are already a clear and present danger to the planet and the ecosystems that support human habitation. The problems are severe and are only likely to become more critical in the coming decades. The human influence on the planet is now so significant that geologists have argued that we have entered the Anthropocene age (Steffen, Grinevald, Crutzen, & McNeill, 2011). We also made it clear that these challenges are anthropogenic and therefore HFE as a discipline is well placed to make a significant contribution to addressing these challenges. As we also acknowledged in Chap. 1, this book does not pretend to address all the challenges raised by sustainability that have a clear link back to HFE. We do believe though that this book makes a significant start. In particular, the chapters in this book indicate that there has now been a great deal of work on reducing various resource use and waste production. Evidence for these types of HFE interventions can be found in Chaps. 4, 5, 6, 7, 9, 11, 12 and 13. This work represents interventions at the personal level (Chap. 4), at the work level (Chaps. 7 and 9), at the public level (Chaps. 5 and 6), and at the government/policy level (Chaps. 11, 12 and 13). This book also contains two chapters on the design of sustainable work systems (Chaps. 3 and 10) and a chapter on corporate sustainability (Chap. 8). The two chapters on sustainable work systems and the chapter on corporate sustainability are each at the work level.

From this overview it is easy to see that there are two obvious gaps in our knowledge. The most glaring omission is work that seeks to develop systems resilient to natural and humanitarian disasters. Moore and Barnard (2012) have published some work in this regard as have Meshkati, Tabibzadeh, Farshid, Rahimi, and Alhanaee (2016). As we create and build more complex, dangerous systems in close proximity to communities, the risk for a major crisis increases dramatically as evidenced by recent disasters at Fukushima, Deepwater Horizon, the tsunamis in Japan and Indonesia, and flooding from Tropical Storm Sandy around New York. There are concerns that these events are a portent of what is still to come. The second omission is with regard to what HFE can do to influence behaviour at the personal level. Since HFE is primarily concerned with work contexts, it is not surprising that much of our effort has gone towards understanding what we can do to address sustainability challenges at the local, public, and regional level because this is where financial incentives can be more readily realised. However, the HFE interventions themselves might not be sustainable unless it is people themselves that change their behaviours. In part, Chaps. 4, 5 and 6 address or review research that is aimed at addressing behaviour change at the personal level, but clearly more work is needed from the HFE discipline in this regard.

Finally, we would like to suggest that one of the limiting factors in connecting sustainability and HFE is the current definition of HFE. The International Ergonomics Association's website gives the following definition, approved at the IEA Congress in 2000:

> Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

We would argue that this definition implies that the systems of interest to HFE are closed systems with linear relationships between humans and the other components of the system. We feel that this is not the most up-to-date view of the types of systems with which many HFE researchers and practitioners actually engage, with many more systems now requiring a more complex, systemic understanding. This would imply the need to consider an expanded definition in order to include these types of systems. Wilson (2014) and Walker et al. (2017) have already challenged HFE to think beyond linear systems to embrace the complexities of system ergonomics. In this book, we embrace the emerging notions of systems ergonomics and invite HFE to extend systems thinking to include the wicked problems (Murphy, 2012) associated with sustainability challenges.

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