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## Editorial: Ergonomics and Sustainability Special Issue

The significance of sustainability has developed and spread during the past two decades, permeating widely through political, industrial, commercial, scientific and other channels. This special issue of *Ergonomics* reflects on the impact this has had and is having on the field of ergonomics and human factors.

Several of the contributions to the special issue indicate how the meaning of the term 'sustainable' has shifted and evolved over the years. With earlier use, dating back to the middle ages, the meaning was of something capable of being maintained or likely to endure. More recently, the term has been adopted in connection with reducing consumption and a more active role for humans in protecting the environment. Recent commentaries on sustainability reflect this shift in emphasis and often take as a starting point definitions such as:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."  
*United Nations Brundtland Commission 1987*

"Sustainable development is improving the quality of human life while living within the carrying capacity of supporting ecosystems."  
*World Conservation Union, United Nations Environment Programme, World Wide Fund For Nature 1991*

Although broad and overarching, these moves to advance a sustainability agenda have led to wide ranging international action, seeking to make improvements in areas such as:

- consumption and production
- built environment and resource utilisation
- land use and agriculture
- transportation
- energy generation and supply
- waste and recycling

Human characteristics, behaviour and performance, and human interactions with technology are vital elements of these. There exists, it would seem, a natural synergy between these areas and ergonomics, with its goal of understanding and optimising the outcomes of human-system interactions. More recently, conceptions of sustainability have extended beyond concerns over the use and preservation of the planet's natural and physical resources, to include the sustainability of organisations and the sustainable use of human resources. Again, ergonomics and these aspects of sustainable development might be expected to be natural bedfellows.

Although ergonomics and human factors is of its very nature frequently concerned with achieving sustainable outcomes there has, until recently, been little direct connection made with the sustainability movement itself. There was of course Moray's notable address to the 12<sup>th</sup> Triennial Congress of the International Ergonomics Association (IEA) in Toronto 1994, addressing the ergonomics of global problems. In his address, Moray looked forward to a world of increasing population, shortages of water, food and energy, accompanied by extensive pollution. He described the world of ergonomics at that time in the mid-1990's as being the world of western liberal capitalism and largely focussed on the concerns of industrialised societies (Moray, 1995). In a self-acknowledged pessimistic view of the future, in this and a later paper (Moray, 2000), he highlighted the contribution ergonomics could make in addressing 'global ergonomics', what could readily now be termed sustainable development.

Zink, in an invited plenary paper presented at the 15<sup>th</sup> Triennial Congress of the IEA, Seoul, 2003 (Zink, 2005), argued for the benefits of considering occupational health and safety as a corporate social responsibility. Zink then referred to the position of corporate social responsibility as a key pillar of sustainable development, alongside economic growth and ecological balance, this then providing motivation for organisational attention to the health and welfare of workers. Judging by the citations to the paper, however, Zink's recognition of opportunities for ergonomics from the sustainability movement gained little traction at the time.

In another opinion paper, Scott (2008) echoed Moray's earlier observation on the discrepancy between ergonomics focusing on the problems of the affluent, technologically advanced world and the considerable opportunity for ergonomics to make more of a difference addressing the problems found in industrially developing countries (IDCs). Scott, pointing to the declarations at the 1992 Rio Summit on sustainable development, argued for a sustainable ergonomics ethos, deploying both micro- and macro-ergonomics to the benefit of development in IDCs.

At the beginning of 2008, a special issue of *Ergonomics* was devoted to 'The Future of Ergonomics' (Stanton and Stammers, 2008). This comprised a collection of peer commentaries from leading colleagues in the ergonomics community, reflecting on predictions made by Sir Fredric Bartlett in his landmark paper published in the 1960's. It is interesting that among the collection, there is only limited reference to ergonomics and sustainability. Of the 10 commentaries, only two (Drury, 2008; Guimarães and Soares, 2008) addressed this directly. Drury mentioned sustainability alongside changes in technology and enterprise as major trends affecting human populations. Drury went on to describe the situation as being in 'overshoot mode', with certain critical factors of the earth's carrying capacity already having been reached two decades previously. Drury concluded "In the future, all of our actions as ergonomists will have to take into account their impact on sustainability". In the context of contrasting the issues facing the developed and developing world, Guimarães and Soares again voiced Moray's cry for ergonomics to devote attention to global problems.

Although there have been commentators calling for ergonomics to become more involved with sustainability, until recently there has been little by way of ergonomics investigation or research explicitly contextualised as addressing sustainability per se. Of the limited work published prior to us embarking on this special issue, Genaidy and colleagues explored ergonomics aspects of business sustainability through two detailed case studies of manufacturing companies (Genaidy et al 2009, Genaidy et al 2010). Genaidy et al considered business sustainability as being achieved where an organisation has "...adapted its practices for its own economic gains for continuity purposes and the use of renewable resources and holds itself accountable for the environmental and human rights impacts of its activities", i.e. protecting the 'triple bottom line' of financial, social and environmental outcomes. Genaidy et al illustrated the complex socio-technical system pathways affecting business sustainability in their study organisations and demonstrated how the ergonomics approach can be of benefit in analysing and identifying potential improvements.

A further instance where ergonomics research has been deployed to address aspects of sustainability has been to examine the problems posed by waste and recycling (Engkvist, 2010; Engkvist et al, 2011). The drive to preserve resources and reduce waste has led to the development of unfamiliar socio-technical systems, with the rapid expansion of recycling presenting new challenges with the design of facilities, the organisation of processes and work, and in influencing the behaviour of users. Engkvist and colleagues, in a programme of research in Sweden, collected evidence on the health and safety status of workers in the recycling industry, examined processes

and influences involved in the activity of waste sorting, and described the characteristics and behaviours of users. This resulted in wide ranging recommendations for improvements.

In summary then, since Moray's call for attention to global ergonomics in the mid-1990's, a search across the core ergonomics journals *Ergonomics*, *Applied Ergonomics*, *International Journal of Industrial Ergonomics*, *Theoretical Issues in Ergonomics Science* and *Human Factors*, has yielded only a small number of contributions up to the end of the first decade of the 21<sup>st</sup> Century making a clear connection between ergonomics and sustainability.

Despite a slow start with the ergonomics community reflecting wider societal attention to sustainability, more recently there has been growing interest and activity. In 2008 the International Ergonomics Association (IEA) endorsed the formation of a *Human Factors and Sustainable Development* Technical Committee, intended to build an international network of experts in the fields of ergonomics and human factors and sustainability. In 2012, the 18<sup>th</sup> triennial congress of the IEA, held in Brazil, led with *Designing a Sustainable Future* as its theme.

These developments led to the inception of this special issue, which draws together contemporary research and thinking on sustainability from across ergonomics and human factors. In response to a call for papers in 2011, over 70 papers were submitted for consideration, a much larger number than usually received for special issues in this journal. Of these, 17 papers were accepted for publication following peer-review. This collection of papers demonstrates the discipline's interest in sustainability, with papers spanning a range of theoretical, conceptual concerns and areas of application.

The first group of papers in the special issue attempt to define the scope and challenges involved in integrating sustainability within a future agenda for ergonomics. Zink and Fischer begin by asking the question 'do we need sustainability as a new approach in human factors and ergonomics?'. Following a résumé of how the interactions between ergonomics and the sustainability movement have developed over the history of our discipline, Zink and Fischer identify synergies and mutual benefits between the two: research, findings and practice in ergonomics are relevant to achieving sustainable development; ergonomics could benefit from increased attention to the whole life-cycle perspective and an impetus for new innovative approaches. In contrast, Dekker et al advance the provocative proposition that the current positivist, empiricist philosophy of ergonomics is incompatible with addressing the challenges and complexity of sustainable development. Despite considering that "...ergonomics has an important and potentially crucial role to play in all sustainability efforts", Dekker et al argue that ergonomics needs to break away from a reductive approach and actively embrace complexity and emergence, the requirements for this being reconsideration of our ethical stance and revision of the curricula of ergonomics education. Dekker et al present a cogent argument on the contradictions between the prevailing epistemology of ergonomics and it being effective in addressing problems of sustainability. Dekker and his co-authors have less to say, however, on how the paradigm shift they call for might be brought about.

Martin et al conducted a literature review, spanning 1995-2012, to examine the involvement of ergonomics in sustainability and sustainable design. The review identified just 14 peer-reviewed journal articles which met the relevance criteria for inclusion. Martin et al conclude that hitherto, the contribution of ergonomics to sustainability has been limited, despite the congruent goals of sustainability and ergonomics. In the literature, the contribution has mostly been one of commentary, with little by way of methods towards or evidence on achieving sustainability goals. Martin et al reiterate the conclusion of other authors that there is considerable scope for ergonomics to contribute to sustainability but there is a pressing need to 'seize the day'.

The separate papers of Thatcher and Hanson are both concerned with 'green ergonomics'. Zink and Fischer express concern over use of the term 'green' as suggesting too narrow an emphasis on natural ecology and the environment, downplaying social and economic aspects. Thatcher, however, argues that there is a place for green ergonomics, concentrating on human-nature interactions, with a pro-nature focus. By way of examples, Thatcher highlights the design of low resource systems and products, the design of green jobs and achieving systemic behaviour change, as areas where ergonomics could contribute to conserving and restoring nature and allowing humans to benefit. Hanson discusses green ergonomics from the perspective of the ergonomics and human factors profession, identifying a series of examples of issues posed by developments in sustainability where ergonomics could contribute (e.g. issues with the installation, commissioning and operation of wind energy generation; health and safety in recycling industries; working practices in organic farming). Although Hanson sees opportunities, she highlights the reoccurring challenge for ergonomics in that what we have to offer may not be appreciated in areas which would benefit from our expertise. Thus, the need for strategies, such as advocated by Dul et al (2012), for promoting ergonomics and the profession.

Following on with the green ergonomics theme, Durugbo, in what he terms an 'eco-ergonomics' study, explored user interactions with recycling facilities (recycling chimneys) in public buildings using a mixed method approach. Three main challenges identified with effective use of the facilities were: appropriate location to encourage recycling, attitudes of intended users to recycling, and presentation of information to users to guide their use. Focussing primarily on the third of these, design features of the facilities were modified to improve the instructions and affordances. A comparative evaluation of the existing and redesigned recycling facilities over 3 months found that the volume of items recycled increased and the accuracy of waste sorting by users improved with the redesigned chimneys. Although of modest-scale, Durugbo's study illustrates how the application of ergonomics approaches to design and evaluation can lead to improvements, with findings generalizable to the design of other recycling facilities.

Nadadur and Parkinson consider the role of a stock in trade of ergonomics, anthropometry, in designing for sustainability. They identify three ways in which data and techniques from anthropometry can generate sustainable design: reducing raw materials consumption by designing appropriately for the user population; increasing usage lifetimes by accommodating future population trends; and through allowing the ethical implications of designs to be considered, particularly disaccommodation of certain user groups. Nadadur and Parkinson demonstrate how these three aspects of sustainability can be addressed through the case study example of designing a seat for an industrial workstation, intended to be used in countries in Africa, Asia, Europe and North America.

Three papers deal with ergonomics aspects of domestic energy consumption and conservation. Stedmon et al examine how on-site micro-generation electricity production, e.g. photovoltaic or micro-wind, affect user behaviours and attitudes towards energy consumption. This is important since, as Kobus et al point out with their study of user interactions with a household energy management system (EMS), local forms of energy production are often not demand driven, with availability fluctuating depending on 'when the sun shines or when the wind blows'. From an analysis of three published case studies, Stedmon et al conclude that the provision of accessible feedback on energy use, through a well-designed user interface, is important in achieving behaviour change and reduced energy use. Kobus et al conducted interviews with households who had used the EMS 'Smart Wash' for several months, with their findings indicating that likelihood of behaviour change depended on a combination of the users' motivation, contextual factors and the design of the EMS. Also looking at domestic heating control instrumentation, Peffer et al conducted a usability evaluation of five existing programmable thermostats and found interfaces that ignored

basic ergonomics conventions and which were complicated and unintuitive, hindering their effective use. Derived from the evaluation, Peffer et al present heuristic guidelines for thermostat design.

The heating and lighting of buildings, domestic, commercial and public, results in significant energy consumption and energy waste. In the case of existing buildings, how they are operated and maintained are important factors in this. With this in mind, Lee and Kang surveyed facilities managers of public buildings in Korea to identify determinants for the adoption of sustainable facilities management (SFM) practices. Lee and Kang found that perceived economic advantage was the strongest predictor, followed by providing for human comfort. Perceived complexity or difficulty implementing SFM practices was not a predictor for adopting SFM. The findings of this study contribute to strategies for increasing engagement in SFM. New buildings, on the other hand, provide the opportunity to optimise energy use from the outset, a proviso being that user characteristic and needs are given proper consideration in the design. Unfortunately, this is not always the case. Hedge and Dorsey carried out a post-occupancy survey of two recently constructed college buildings in the USA. Both buildings were certified to the highest category under the national Leadership in Energy and Environmental Design certification programme and as such should reflect a high level of 'green design' as per standards prevailing at the time of construction. Although the two buildings were energy efficient, Hedge and Dorsey found problems with indoor environment conditions that affected the perceived health and performance of the occupants. Hedge and Dorsey conclude that building rating schemes should also incorporate mandatory measures of performance against ergonomics criteria, as well as evaluating energy performance.

Transportation is another major area of energy use and environmental impact, where significant efforts are being directed at improving efficiency and reducing consumption. Vehicle design is an area of technological innovation, with developments in alternative fuel engines and power units, coupled with systems to deliver increased efficiency. Many of these bear on the nature of the driving task and depend on effective human interfaces. Harvey et al's paper is concerned with attitudes and behaviour around 'eco-driving' (driving behaviour aimed at reducing fuel consumption and CO<sub>2</sub> emissions). From their survey work with both domestic and fleet drivers, they found that among their participants, environmental considerations for drivers were of lower priority than comfort and convenience and not enough, even when coupled with saving money through increased fuel efficiency, to influence patterns of driving. Harvey et al suggest that possible benefit of in-vehicle feedback systems on fuel consumption were likely to be limited to the minority of drivers already interested and motivated to engage in eco-driving. Thus, a precursor to benefits from technology that requires driver engagement is changing driver attitudes towards fuel efficiency and incentives which reinforce this. Stanton et al address the Intergovernmental Panel on Climate Change's call in 2007 for a 'modal shift' from personal car use to public transport. These authors applied the ergonomics and human factors technique Cognitive Work Analysis (CWA), a tool which facilitates the analysis of complex socio-technical systems, to explore and map the barriers that exist to achieving a modal shift to travel by rail. This paper is interesting in both demonstrating how tools in ergonomics might provide novel and informative perspectives on complex sustainability problems, but also with the seven intervention strategies identified through the analysis that might encourage a major shift to rail use.

Ryan and Wilson's paper is also rooted in rail transportation, a form of transport commonly viewed as beneficial in terms of sustainability. Intriguingly, however, the paper is more concerned with the development and implementation of sustainability policies and practices within a railway organisation, rather than rail transport itself. Noteworthy findings from their study involving interviews with senior managers were improved understanding of the sustainability vision at senior level in the organisation and in clarifying organisational requirements for effective implementation of a policy on sustainability. Ryan and Wilson explain the rationale for the ergonomics contribution

to the investigation as being: expertise working with varying stakeholders and navigating between their differing goals; the bringing of a systems perspective; our ability to contribute to potential solutions involving human elements and interfaces. Reflecting on their study, as per Zink and Fischer, Ryan and Wilson highlight the much longer time cycle with sustainability between actions and outcome. Similarly to Dekker et al, Ryan and Wilson mention ethical questions associated with the involvement of ergonomics in this area. In contrast to the rail sector, the minerals industry is directly concerned with exploiting the planet's resources. Horberry et al describe, however, how it is possible to apply sustainable development philosophies to minerals extraction and processing. Referring to the International Council of Mining and Metals' 10 principles of sustainable development, Horberry et al suggest ergonomics could readily make a significant contribution to almost all of these. Treating 3 of the principles as case studies, Horberry et al describe current ergonomics research addressing these.

The final paper in the special issue considers the role of ergonomics in sustaining a healthy and productive workforce. Bridger et al present the findings of a cohort study, which compared health and lifestyle data for 1,069 Naval personnel by means of surveys undertaken in 2007 and 2011. Almost  $\frac{2}{3}$  of those surveyed were either overweight or obese, with high BMI associated with development of health problems including back pain, musculoskeletal conditions and high blood pressure. Health risk in 2011 was predicted by low participation in exercise in 2007. In terms of achieving a good (sustainable) person environment fit, Bridger et al suggest that secular changes, especially with BMI, may mean that the working populations of many countries are no longer represented by those on which the knowledge base of ergonomics was developed. Questioning the sustainability of sedentary work, Bridger et al emphasise the scope for innovations in job and workplace design to encourage beneficial physical activity.

So what might reasonably be concluded from the collection of papers in this special issue? It is apparent from the large number of submissions in response to the call for papers that there is wide interest in the topic. From the papers that made it through to publication, however, the current contribution of ergonomics to sustainability appears to still be skewed towards recognising what ergonomics has to offer and calling for its involvement rather than actually being involved in delivering sustainable development solutions. Ergonomics activity on this front appears limited and tentative. Perhaps we should be looking now for ergonomics to be doing more to move beyond stating its importance and relevance within this area, towards applying the existing body of knowledge to the design of interventions and improvements, bringing us closer to a sustainable future.

Although the coverage of the papers here is broad, spanning energy use, buildings, mining, transportation, recycling and human resources, there are some notable areas missing. Sustainability and agriculture is one area where ergonomics might be expected to have something to say. Within transportation, papers are included dealing with road and rail, but aviation also has significant ergonomics aspects of sustainability to address. Considering other areas in which ergonomics is involved at present, the contents of this special issue does not reflect any sustainability connections or concerns that might be present in healthcare or military ergonomics. It is possible that in these spheres of activity other priorities other than sustainability (e.g. efficacy and efficiency concerns) are currently paramount. It will be interesting to see if this changes in the future and sustainability becomes more firmly embedded within a wider agenda for ergonomics research and practice.

Our goal in compiling this special issue was to catalogue and raise the profile of existing work in the area of ergonomics and sustainability. This is represented by the 17 papers published in the collection. We also hope that the special issue will stimulate future research and practice in a field that is likely to become of increasing relevance and importance as the century proceeds.

Special Issue Editors:  
Roger Haslam  
Patrick Waterson

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