A Socio-Technical Perspective on the Application of Green Ergonomics to Offices

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ABSTRACT

We explore the potential for offices to provide organisations with the adaptive capacity to respond to the chronic challenge of environmental sustainability. We apply a socio-technical systems perspective and green ergonomics principles to investigate the relationship between an office environment, the occupants working within it, and the wider environmental context. To do this, we explore technical and cultural perspectives, and integrate these in a socio-technical viewpoint. In doing so, we consider the interaction between technical factors, such as green technology, and social factors, including social norms, which influence occupant activity and the contribution of this to the overall environmental performance of an office. We also consider how a green office might provide non-carbon benefits such as improving occupant well-being, creativity, and supporting the emergence of a green organisational culture, particularly through the application of biophilic design. Our investigation highlights several avenues through which an office designed with green ergonomic principles could benefit occupants, the organisations they work for, and the natural environment of which they are a part and on which they depend. We find reason to suspect that green offices could play an important role in sustainable development and exemplify how "going green" may be good for business.

Introduction

Government targets around net zero emissions demonstrate that sustainability is now a mainstream priority for business. Beyond being a business priority, scholars recognise that sustainability is an essentially *human* activity (Pfeffer, 2010). In response to this imperative, modern businesses (and not just those on the green fringe) are publishing net zero (and, more recently, net gain) ambitions and building action plans to adapt to a changing regulatory environment; one in which poor environmental management will carry tangible consequences. Board members, sensibly, want to avoid following in the footsteps of peers now facing criminal charges for failing to demonstrate effective governance (e.g., see Campbell & Vladkov, 2021).

More recently still, the focus of business since 2020 has been on the acute issue of COVID-19, and companies globally are undergoing a rapid transformation in response to this pandemic. As countries around the world entered various forms of lockdown, organisations experienced a radical shift as office-based staff began working remotely to curb the spread of the virus. This represents a sudden acceleration in the trend towards remote working (Global Workplace Analytics, 2017). The full implications of this mass remote work experiment will emerge over time, and might also include changes in employee office schemas, and how organisations use their office space.

In this review, we propose that offices sit at the confluence of organisations trying to take meaningful steps towards reducing their environmental impact, whilst adapting to post-pandemic ways of working. In imagining the office of the future, we consider how such a space could enable organisations to reduce their environmental impact while simultaneously providing a working environment that supports employees' health, well-being, and productivity.

To conduct our exploratory review, we included research literature spanning human factors, workplace, organisational behaviour, environmental psychology, and engineering fields that overlap to create the topic area of green ergonomics. We unpack this literature by first reviewing the green ergonomics field, which focuses on developing human systems that integrate with the natural environment. We then consider the office from technical (e.g., conserving, preserving, and restoring nature), cultural (e.g., as a projection of a company's environmental values), and socio-technical (e.g., providing benefit to occupants) aspects as these pertain to sustainable development.

Green Ergonomics

As with many disciplines, ergonomics is adapting to the imperative of sustainable development (Steimle & Zink, 2006). Accordingly, contemporary research and practice contributes to a growing literature that considers how ergonomics can integrate sustainable development alongside existing priorities (Thatcher et al., 2019). Within this literature, green ergonomics has a specific focus on the environmental impact of work systems (Thatcher, 2013). Green ergonomics applies ergonomic principles, perspectives, and methods to support sustainable development through the design of work systems comprising multiple elements, including workspaces. A key distinction between green ergonomics and other similar areas, such as green supply chain management and green production, is the focus on the individual as the fundamental unit of analysis.

In the context of sustainable development, green ergonomics is rooted in the concept of the "triple bottom line" (Zink et al., 2008), which advocates the view that genuine sustainability meets environmental, social, and economic needs. Accordingly, the goal of green ergonomics is to design systems that are efficient and effective from ecological, economic, and social perspectives. Thus, green ergonomics can make a valuable contribution towards sustainable development by focusing on the interaction between people and the built environment. In this regard, Thatcher and colleagues (2013) propose four design principles that serve as a framework for green ergonomics, which we interpret in the context of office design from the perspective of office workers.

Principle 1 - green ergonomics should promote eco-efficiency, eco-effectiveness, and eco-productivity. In the context of office workers, design aligning to this principle minimises the energy workers require to complete their tasks (e.g., demand on cognitive resources to filter extraneous noise), and provides sufficient access to restoration (e.g., through the provision of quiet spaces and elements of biophilic design) so that the interaction between workers and their workspace is sustainable.

Principle 2 - green ergonomics should promote ecological resilience by preserving the capacity of the workplace environment to absorb disturbances without change to its structure or function (i.e., the emergent dynamic stability that is a characteristic of complex adaptive systems; Lansing, 2003). In complex adaptive systems that feature dynamic interdependencies among independent components, such as organisations, stability is an emergent process (Eidelson, 1997). That is, the system finds a balance not through top-down design, but bottom-up through the dynamic interaction of components as they exchange energy and matter, such as information and resources.

Principle 3 - green ergonomics should accommodate indigenous/vernacular solutions to local problems. This implies understanding local requirements using a participative approach to arrive at an optimal design solution, and satisfying those requirements using local resources. For example, a

green ergonomics approach to office fit-out would include consultation with users regarding their requirements for office furniture; and contracting local manufacturers to provide this (ideally using local materials).

Principle 4 - green ergonomics should acknowledge the interaction between natural systems and design. At one end of a spectrum, design can consume more natural resources than it requires, producing excess waste and failing to support the restoration of those natural resources. Sustainable design aims for a neutral impact and acknowledges the inherent uncertainty of complex systems by taking a precautionary stance (Orr, 2002). At the other end of this spectrum, regenerative design strives for a net *positive* effect on the natural environment by restoring, renewing, and/or revitalising the natural resources it consumes (Cole, 2012).

A green ergonomic perspective thus considers the interaction between human, technological, and natural systems. From this perspective, offices aligning to green ergonomic principles constitute effective working environments that support worker, organisational, and ecological requirements. In the next section, we develop this idea a step further, and explore how such offices can be exemplars of sustainable development from three different perspectives: (1) technical, (2) cultural, and (3) socio-technical.

The Technical Approach to Green Ergonomics

The carbon intensity of an office is a prime target for companies seeking to align themselves with sustainable development. The environmental performance of green buildings can be fragile, owing to the complexity of their design (Leaman & Bordass, 2007). In our view, green ergonomics could moderate this fragility by effectively considering the interaction between the human and technical components of an office to facilitate emergent stability. Lighting and heating/cooling are major sources of demand, and their direct link to the basic needs of building occupants highlights the potential contribution of a human-centered design response. From a technical perspective, a green ergonomic approach applies ergonomic methods to identify and to realise opportunities to effectively reduce energy consumption. We propose two technically oriented avenues through which green offices could integrate into a company's broader sustainability agenda, which focus on infrastructure and technology, and how occupants interact with these features.

Minimising the Environmental Impact of the Physical Office

Green office technology can serve as a tangible and engaging demonstration of an organisation's investment in sustainable development. Notably, however, such technology without a clear understanding of ergonomics will still likely fail to promote efficiency, effective, and satisfying use on behalf of office workers (Martin et al., 2013). Green ergonomics can support this by understanding and optimising the interaction between users and technology.

The prime targets for reducing energy consumption in offices are lighting and heating. Green ergonomics can address these through a detailed understanding of user behaviour and requirements. For example, identifying where lower levels of artificial light are needed based on the task activity in certain areas can reduce light-related energy consumption by 25% without disrupting user comfort (de Bakker et al., 2018). Similarly, investigating activity within different areas can identify more efficient ways to provide thermal comfort, with an appreciation of the interaction between occupants (e.g. clothing, insulation, metabolism) and the environment (air temperature, humidity, local air velocity, thermal radiation). For both, green ergonomics would integrate the effective use of natural light and ventilation, and explore the potential benefits of a moderate amount of environmental variation compared with static heat and light levels.

Helping Employees to Limit their Environmental Impact

That building energy consumption often exceeds design projections (American Physical Society, 2008) suggests these fail to consider the dynamics of user behaviour accurately (Leaman & Bordass, 2007). Such variability is a design parameter in ergonomics (Attiaianese & Duca, 2012) that could identify and proactively address issues that undermine the potential of green technology. While the technical potential of green technologies is important, a green ergonomic approach would further consider user characteristics such as tasks, priorities, and skills to select the most appropriate technologies.

In the workplace, office occupants have considerably less autonomy over the choice of equipment they use than they might have at home. If office workers are unable to influence procurement decisions that determine what equipment they use, their contribution concentrates on how they use this equipment. Ergonomist can support this by developing office user guides that enable occupants' ability to leverage the technology provided to optimise environmental performance. In situations where discretionary user behaviour drives energy efficiency, providing performance feedback is important. Signaling when services such as heating, air conditioning, or lighting is providing negligible benefits (and could be turned off without a noticeable difference) could encourage energy conservation behaviour, provided users can interpret this information to make corresponding behavioural decisions (Payne & Grigg, 2017).

The Cultural Approach to Green Ergonomics

From a cultural perspective, businesses can use offices as a kind of gallery to display artifacts and symbols of sustainable development and project a positive value to supporting sustainability related activity. We now consider how green ergonomics can facilitate a workplace culture that complements the technical aspect we described above, with the intent of encouraging emergent system-level outcomes that make a meaningful contribution to sustainable development. The social contexts of workplaces might be a stronger influence on occupant behaviour than personal attitudes towards sustainable development (Christina et al., 2014).

Culture is an important driver of individual, group, and organisational behaviour, including behaviour aligning with environmental sustainability (Norton et al., 2015). Schein's (1990) structural model begins with fundamental assumptions, which inform beliefs and values, and manifest into tangible artifacts, such as language, procedures, and symbols. The office is thus both a cultural artifact and a gallery for other artifacts (Vilnai-Yavetz et al., 2005). Green ergonomics could help develop and reinforce a workplace culture that aligns with and supports sustainable development.

Cultural Symbols

Like brand names, logos, and uniforms, an office can possess symbolic value for an organisation, although the office is usually considered in terms of utilitarian function rather than aesthetic form. Nevertheless, the physical design of an office communicates corporate cultural values, which in turn influences the social context and influences occupants' normative behaviour (Lindberg, 2019). When individuals interpret the artifacts and symbols within their workplace, including technology, they are also interpreting and evaluating the underlying assumptions, beliefs, and values. Upon entering, a person is likely to use this information to make sense of their environment, and determine how to adapt their behaviour to fit in.

Social Norms

All offices have the potential to display cues that indicate a corporate value towards sustainable development that increase the likelihood that occupants interpret design features within an office as

cues for pro-social normative behaviour (such as reducing energy consumption and waste). For example, BT uses a digital message board featuring information that underlines the organisation's value towards sustainable development, such as partnerships with local charities, upcoming tree planting days, office energy consumption, and tips to reduce personal environmental impact at work (Cox et al., 2012). Applying the principles of green ergonomics could optimise the location of communication material to maximise reach and readability (such as in toilet cubicles) and not in locations where the signal-to-noise ratio is poor (such as message boards in kitchenettes). Displaying normative information in locations where people congregate may facilitate the development of shared perceptions that underpin workplace culture.

Second, an OPO affords greater potential for occupants to observe others engaging in green behaviour. Green ergonomics can, through the design of facilities, procedures, and including features that encourage green behaviour, support the emergence of descriptive norms that demonstrate sustainable development is not just something members of the organisation *talk about* (injunctive norms); it is also something that people in the organisation *do* (descriptive norms), such as through participation in environmental groups, volunteering, and supporting other employees' green behaviour.

A Socio-Technical Approach to Green Ergonomics

According to Lindenberg (2019), the most salient cues for normative behaviour comprise the presence of other people in the environment, indicators of others' normative behaviour, objects associated with the normative goal, and visceral cues. An office integrating green ergonomics would provide the relevant technology and infrastructure, alongside such cues to encourage the efficient and effective use of these, not to mention green behaviours. A green ergonomic approach can create offices that aligns to and supports values towards the natural environment and deeper assumptions about our place in the ecosystem. By supporting both injunctive and descriptive norms, green office can facilitate behaviours that match the context, as well as those that might sit beyond an occupant's role (e.g., partnering with local charities to donate surplus catering). Furthermore, by co-locating group members in a shared space, offices can facilitate the exchange of information (Heinzen et al., 2018), including normative information.

Well-Being and Performance Benefits for Occupants

A person-environment fit perspective emphasises that good offices should support the well-being and comfort of occupants (Hedge, 2008). In this context, well-being refers to a positive state of being that emerges from the interaction of physical, social, and mental components. Thatcher (2015) argues that complex systems, such as organisations, have a duty to maintain their fundamental components, including their people. Indeed, organisations that prioritise occupational and environmental health (as recognized by professional associations) tend to perform well on other measures of corporate performance, such as stock market value (Fabius et al., 2013). This suggests that the health of an organisation according to traditional metrics might rest on the health of its human capital.

Biophilia refers to a fundamental human need to connect with nature. Biophilic design is a fundamental component of green offices and provides cognitive, psychological, and physical health benefits, as well as supporting place attachment (Kellert et al., 2008). Designers can demonstrate biophilic design in three ways: (1) by introducing nature into the space, such as plants, natural light and thermal variability; (2) by providing natural analogues, such as shapes and colors found in nature; and (3) by considering the nature of the space, for example places to interact and places to rest. In the context of green ergonomics, biophilic design thus represents the dynamic interaction between people and their environment; and explains how green offices can support the well-being and performance of workers. By applying green ergonomics methods and principles, designers can

leverage biophilia to create workspaces that not only support occupants' performance at work, but also their well-being and capacity to perform sustainably.

Biophilic design can provide benefits to occupants in multiple ways. First, natural visual stimuli can improve typical cognitive resources office workers use throughout the day, such as concentration and memory (Alvarsson et al., 2010). Second, research shows that viewing nature either before or after experiencing a stressor has beneficial effects in terms of blood flow and brain activity (e.g. Brown et al., 2013). Third, providing sounds from nature, such as running water, bird songs, or rustling trees can facilitate psychological restoration at a rate 37% faster than urban noise (e.g., traffic, construction sounds; Alvarsson et al). In addition to having a restorative effect to support workers capacity to respond to new stressors, nature sounds can also stimulate creative performance (Mehta et al., 2012). Fourth, examples of nature such as office plants can support health and wellbeing by improving air quality and comfort (Han & Ruan, 2020). Finally, biophilic design can alter the extent to which occupants are physically active in the office. For example, biophilic design that encouraged physical activity led to a 40-minute increase in time spent standing after seven months (Wallmann-Sperlich et al., 2019), which could mitigate musculoskeletal issues that can arise from sedentary work.

Conclusions

Biophilic design is evident in the most ancient of human structures, which demonstrates humans are more familiar and suited to spaces that integrate this than an artificial office environment (Ryan et al., 2014). As an analogy, Heerwagen (2006) considered the difference between outdated versus modern zoos, and the apparent effects animal welfare. She argues that, while animals can survive in zoos (in the same way office workers can fulfil their role responsibilities in offices), it is difficult if not impossible for them to thrive in an environment that bears little resemblance to that which a species has adapted to. To address this, modern zookeepers have adopted a philosophy of "environmental enrichment," where they work with biologists to transform animal enclosures to recreate (as closely as possible) different species' natural environments (Mellen & Macphee, 2001). Considering the office environment, green ergonomics is an ideal discipline to transform workspaces similarly into simulating, enriched and nurturing environments that are as much habitats for humans as they are workplaces.

Integrating green ergonomics in a socio-technical approach to office design has the potential to create enabling environments that facilitate workers' positive contributions to an organisation's economic and environmental performance. Within this perspective, green offices could establish the balance between economic, social, and natural capital required as part of sustainable development (Thatcher et al., 2019). If there is truth in the views that (1) happy people are productive people (Belle et al., 2019), (2) healthy people are happy people (Steptoe, 2019), and (3) healthy environments make for healthy people (van den Berg et al., 2013), then using green ergonomics to design offices that support occupants' physical, psychological, and social well-being should, in turn, enable organisations occupying such offices to improve their environmental, social, and financial performance.

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