The Design Journal
An International Journal for All Aspects of Design

ISSN: 1460-6925 (Print) 1756-3062 (Online) Journal homepage: https://www.tandfonline.com/loi/rfdj20

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To cite this article: Yasemin Afacan (2015) Older Workers and a Sustainable Office Environment, The Design Journal, 18:1, 57-82, DOI: 10.2752/175630615X14135446523260

To link to this article: https://doi.org/10.2752/175630615X14135446523260

Published online: 28 Apr 2015.

The Design Journal VOLUME 18, ISSUE 1 PP 57–82 REPRINTS AVAILABLE DIRECTLY FROM THE PUBLISHERS PHOTOCOPYING PERMITTED BY LICENSE ONLY

Older Workers and a Sustainable Office Environment

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ABSTRACT Compared to 20 years ago, there are growing numbers of older office workers globally. Despite the growing importance of 'inclusive design' and a 'sustainable' research agenda, there is little knowledge of what the ageing workforce sector requires, and there is little known about the strengths and weaknesses of current sustainable workspace designs for older workers. This study explores ageing workers' experiences through a field survey of 240 office workers (ranging in age from 55 to 75) in three recently constructed sustainable office buildings. It investigates the sets of common factors in a sustainable building system that influence the experience of older office workers, and analyses the correlations from the perspective of the human factors discipline. This paper discusses the implications of the study on practice from

 DOI: 10.2752/175630615X14135446523260

two points of view: (i) the ageing workforce and (ii) the sustainable development of office buildings, and suggests a number of future research issues regarding a user-responsive workplace.

KEYWORDS: sustainability, older workers, user-responsive workplace, inclusive design, user participation

Introduction

Despite the growing importance of sustainability worldwide, its contribution to successful ageing has not been deeply analysed. The importance of human interactions with sustainable building technologies and systems cannot be disregarded. A sustainable building system must ensure occupants' safety, health, comfort and satisfaction 'while meeting the needs of the present without compromising the ability of future generations to meet their own needs' (United Nations Brundtland Commission, 1987). Little is known about whether these new built environments impose different constraints or provide new opportunities for meeting older people's requirements compared to conventional buildings. Especially in the present situation, where a growing number of office workers will not retire at the expected age, user participation should be embedded in workspace design from the early phases of the design process. A participative process can therefore be 'a way of drawing boundaries around what are acceptable and unacceptable or illegitimate views, and less dominants may be marginalised' (Petriwskyj *et al*, 2012: 183). By 2020, nearly half the adults in the European Union will be over the age of 50 and actively working (Smith, 2008). In this respect, because of age-related decline, a sustainable office environment becomes significant in terms of the human–environment interface. 'Workspace performance is a measure of the effectiveness of a workspace in meeting the occupant needs' (Kim *et al*, 2008: 1286).

There are three critical issues that make it difficult to integrate ageing needs into current sustainable office systems: (i) theory–practice inconsistency, (ii) the designer's lack of expertise, and (iii) a communication gap between designers and older users. A theory and practice inconsistency has emerged because of a lack of human factors specialists and a difficulty in determining the academic source of information (Hendrick, 2008). The second critical issue concerns the importance of ergonomics knowledge. Designing a sustainable office space that meets ergonomics principles is a complex task with a number of interacting and variable elements, such as human–machine, human–environment, human–software and human–job interfaces. The third issue occurs because many sustainable developments disregard human characteristics, behaviour and interaction; if these are considered, they likely only apply to younger users. For example, a workspace may consider sustainable building systems, such as waste management, reduction of CO_2 emissions, and improved water and resource efficiency, but if human satisfaction and comfort are not taken into account, then the system is unsustainable.

In this study, the author addressed the urgent need to investigate the sets of common factors of a sustainable building system influencing the experience of older office workers and to analyse the correlations from the perspective of the human factors discipline. Ageing workers' experiences are explored through a field survey in three recently constructed sustainable office buildings. The aim of the study was not to evaluate the case buildings' performances or demonstrate well-known office-specific standards when designing for older workers, but rather to focus on how indoor environments with sustainable building practices, such as thermal comfort, should address extended working years and be translated into effective buildings for successful ageing.

Ageing and Older Workers' Needs in an Office Environment

The constant changes in contemporary offices due to technological innovation have a large impact on all aspects of product design, architecture and planning. A workspace designed considering required comfort conditions (optimum heat, light and acoustical components) and ergonomic values are essential in terms of workers' performance, health status and job satisfaction (Unver *et al*, 2004). 'The physical environment is an exterior stimulus which influences the individual psychologically as well as physiologically' (Danielsson and Bodin, 2008: 607). Workspace design is much more valid for ageing populations, who are at risk for activity disengagement and health-related decline (Werner *et al*, 2011). However, workspace design problems can be difficult to solve because there are many physical and symbolic factors to consider. For example, a decision to improve collaboration, where team working and interaction is vital, may affect privacy, as is evidenced in many of today's open-plan office environments (Anjum *et al*, 2004). But because collaboration needs cannot be met through individual private workspaces, there should be a balance between building collaborative spaces and spaces that meet individual needs. As another example, designing to increase natural light can affect glare and create visual discomfort, especially for older workers, who are likely to have more vision problems than younger ones. Thus, lighting admission should be controllable and correspond to individual needs.

Changes in the traditional concept of a workspace have also resulted in diversification of the user profile. According to Vischer (1996), modern office workers are increasingly aware of the possible impacts of the work environment and thus are demanding healthy and comfortable spaces with higher building performance and ergonomic considerations. Compared to 20 years ago, there are growing numbers of older office workers in developing countries; retirement age is increasing globally (Smith, 2008). In Turkey, where the ageing population is an increasing concern (Afacan, 2008, 2013), older office workers are finding work in another firm after they retire from their original firm. Reasons for this changing trend are as follows: their pension funds are not enough to provide for daily basics; work provides a structure to life and important social networks; due to longer life expectancies people are expected to be able to work actively after the usual retirement age (65 in Turkey); and firms prefer older workers' experience and expertise for consultancy purposes (Turkish Ageing Sciences and Technologies Institution, 2011).

Due to older workers' needs, then, workspace design should change to accommodate them. Despite the recent 'inclusive design' research agenda, there is little knowledge of what the older workforce sector requires, and there is little known about the strengths and weaknesses of current sustainable workspace designs for older workers (Stubbs *et al*, 2008). A review of the literature indicates that there is much debate on the appropriateness of the components of the contemporary and sustainable office work system. Although due to convenience and lower costs, the open-plan office continues to increase, how it engages with older workers' requirements is questionable. According to the Welcoming Workspace project, which was conducted by the Helen Hamlyn Centre at the Royal College of Art in London, Kyushu University in Japan and the University of Melbourne in Australia to investigate the requirements of older office workers, the open-plan office does not adapt well to ageing workers' needs (Smith, 2008). The project findings also illustrate that hot-desking, which is defined as shared workstations on an as-needed basis (Anjum *et al*, 2005), is detrimental to collaboration and concentration. The Welcoming Workspace project summarized the needs of older office workers under five key issues: (i) vision, (ii) hearing, (iii) ergonomics, (iv) cognition and (v) health and well-being.

Humans experience an age-associated decline in vision, and many studies have reported glare and visual discomfort problems when daylighting has been maximized in energy-efficient technologies (Galasiu and Veitch, 2006; Knez and Kers, 2000; Sutter *et al*, 2006; Webb, 2006). However, 'It is important to realize that daylighting is not "only" an energy-efficiency technology but also an architectural discipline, and a major factor in occupants' perception and acceptance of workspaces in buildings' (Reinhart and Selkowitz, 2006: 715). Acoustical considerations are also important for older people, who may find background noise more disruptive. According to Jensen *et al* (2005), the open-office environment needs to be designed to consider speech privacy and intermittent noise, because older people generally cannot hear well at higher frequencies. Due to reduced physical abilities, such as loss of muscular strength and changes in posture, balance and joint movement, older workers need adjustable furniture with higher levels of ergonomic comfort, adequate spaces for movement and circulation, clear lines of sight and easy access to office system components (Dainoff, 1990; Francis and Dressel, 1990; Kroemer and Kroemer, 2001; Marmaras and Papadopoulos, 2003;). Older workers' reduced mental capacities require easy navigation, simple and clear layouts, and non-obstructive accesses to, in and around offices (Margaritis and Marmaras, 2007). The fifth requirement, sustaining health and well-being, is as essential as the other four. Providing alternative work and socialization spaces (such as a gym, cafeteria etc.) is beneficial to a healthy atmosphere (Smith, 2008). In that sense, job redesign, alternative work and compensatory physical conditioning are among the options available for creating safe working environments for ageing employees (Fozard *et al*, 2000).

In addition to the five factors noted above, workplace privacy is another vital issue because it critically affects task performance and work-related attitudes (Anjum *et al*, 2004, 2005). Anjum *et al* (2004) define privacy as control over accessibility to oneself and the ability to maintain confidentiality. Inadequate privacy conditions do not only affect workers' concentration, but also create over-demanding alertness, difficulty in getting along with colleagues and problems when discussing sensitive matters (Anjum *et al*, 2004). The current study differs from the above studies by revealing which associated common factors of sustainable workspaces' interior systems (furniture, lighting, ventilation, heating, acoustics etc.) meet the standards of a user-responsive office environment, and how they contribute to sustainability. The study thus does not consider older workers' needs in isolation, but in the context of sustainable strategies that can improve working conditions.

Sustainable Strategies for Indoor Environmental Quality

Due to its multifaceted character, sustainability in the built environment is difficult to define. The concept of sustainability has become an overarching principle in many national and international studies since the publication of the United Nations' Brundtland Report (1987) and the 1992 Rio Earth Summit, which put human beings at the centre of concern for sustainable development and outlined the goal for humans to live healthy and productive lives in harmony with nature (Birkeland, 2002). Sustainable design is a philosophy that aims to maximize the quality of the built environment while minimizing or eliminating the impact on the natural environment, and its main goals are as follows: (i) minimize energy requirements and utilize renewable energy, (ii) use local materials, (iii) increase habitat for biodiversity, (iv) eliminate air and water pollutant discharges and enhance environmental quality, (v) provide healthful and accessible environments for occupants and (vi) embody a vision of positive human participation in our living planet (Birkeland, 2002). The essence of sustainable development lies at the interfaces of its three dimensions – environmental, economic and social – but ‘the social dimension has commonly been recognised as the weakest “pillar” of sustainable development’ (Lehtonen, 2004: 199) because the interaction between the environmental and the social is still uncharted (Afacan and Afacan, 2011). Thus, in addition to accommodating physical environmental factors, understanding human interactions with sustainable systems is a prerequisite for managing indoor environmental quality; sustainable innovations have a profound influence on ergonomics.

‘Typical benefits of sustainable buildings include savings in operating costs and an increased bottom line through higher employee satisfaction and job performance due to the better quality of the indoor environment’ (Lee and Guerin, 2010: 1104). Creating comfortable environments is not only important for human factors, but helps to reduce the need for reconstruction and renovation. Indoor environmental quality, which affects user satisfaction, performance and productivity, involves a comprehensive approach towards lighting, acoustics, noise control, ventilation and thermal comfort. According to Leadership in Energy Environmental Design (LEED), a green building certification and rating programme in the USA, indoor air quality (IAQ), thermal quality and lighting quality are the three aspects of indoor environmental criteria most affecting employee satisfaction and performance (US Green Building Council, 2000). Common global standards for indoor environmental quality exist, such as those from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the Green Seal Standards, ‘[h]owever, there is no evidence that the indoor environment designed according to these standards is comfortable and productive for occupants’ (Lee and Guerin, 2010: 1105). Maver and Petric (2003) state four conditions for sustainability: fitness-for-purpose, cost effectiveness, environmental friendliness and cultural significance. Winchip (2007) divides sustainable strategies for indoor environmental quality into two categories: (i) spatial and (ii) mechanical. The spatial strategies are related to positioning doors and windows, specifying appropriate furniture and locating it corresponding to its function, identifying effective use of vertical and horizontal space, planning effective paths of circulation and determining the ideal proportions of a room based on the activity. Mechanical strategies include appropriate planning for safety, security, thermal comfort, noise reduction, daylighting, views to the outdoors and natural ventilation.

Much of today’s built environment is not constructed based on these four conditions and two types of strategies. Over-engineered buildings are especially preoccupied with technological sustainability solutions, disregarding human satisfaction and environmental quality. To meet requirements for older people, buildings and nature, a balance between architectural and mechanical preferences must be achieved.

Methodology

Setting

This study was carried out in three sustainable office buildings in Ankara, Turkey. The building selections were based on the following criteria: (i) was constructed according to sustainable principles, (ii) has a LEED Green Building Certificate, the highest possible certification in the LEED system, (iii) has a high number of workers over age 50 and (iv) has office spaces built according to an open-office layout. It is important to note that the aim of the study was not to evaluate how well the selected buildings were designed for older workers, but rather to analyse employees' experienced age-related difficulties within a sustainable system and their rating of sustainability criteria for an ideal office environment. Different to the conventional building development process, the case buildings were designed based on an integrative approach considering site conditions, renewable sources, energy systems, building codes and local sources of materials. Table 1 lists the achieved sustainable systems of the three buildings.

Data collection

The author conducted a quantitative correlational study, developing a survey instrument with a comprehensive list of 46 items to gather the data (See Appendix A: The Survey Instrument). The instrument was a structured questionnaire with closed-ended questions covering various aspects of a promising sustainable office environment. Composed of two main sections, the first section related to employee demographics. The second section concerned the physical properties of the environment and was composed of six subsections, pertaining to lighting comfort, acoustic comfort, ergonomics, wayfinding, IAQ and thermal comfort. The questionnaire was developed by a focus group of academics working on office design, sustainability and ergonomics, and was then tested and refined on the basis of LEED's IEQ category. Users were asked to rate their importance level for each item on a scale of 'one' to 'five' ('one' being the least important and 'five' the most important), and to mark the appropriate boxes to identify how important each feature is in working successfully within a sustainable office environment. Items that may not have been clear to participants were explained. Further information for the study was obtained through an unstructured interview, which helped with examining the results comprehensively. To avoid biases, the interviews were done in private.

Sample group

The target group of the study was older workers in the office buildings. A total of 240 randomly selected employees participated in the survey, ranging in age from 55 to 75 (mean age = 66.90; participants' demographics are shown in Table 2). The study considers someone

Table 1 Green features of the selected office buildings

Green features	
Energy efficiency	Increased insulation throughout the building Triple-glazed windows Reflective green roof coating Light tube system High-efficiency lighting system Lighting control system Indoor and outdoor motion sensors for lighting Ground source heat pump Cogeneration unit Ice storage tank and thermal storage system
Water efficiency	Grey water recycling system Drip irrigation system Low-flow water fixtures Dual-flush toilets Native, drought-resistant plants with low water needs
Renewable energy	Photovoltaic system Wind turbine Green power usage
Indoor air quality	CO_2 monitoring Low volatile organic compounds (VOC) paint and finishes Operable windows for natural lighting and ventilation
Material efficiency	Construction waste recycling Recyclable carpet with high level of recycled content Recycling bin storage area Non-toxic, durable and local material selection
Site planning	Bicycle parking area Alternative transportation opportunities

aged 55 years or older as an 'older person' because the Turkish definition of 'elderly' correlates with the chronological age of 55, and is appropriate to the chronological, functional and social dimensions of ageing in Turkey (Turkish Ageing Sciences and Technologies Institution, 2011). The age of 55 is also critical because the decision to remain in the workforce or fully retire is made between the ages of 55 and 64 years (Adler and Hilber, 2009). None of the respondents had any disability; however, they did have common age-related vision, hearing (difficulties with filtering background noise), motor (loss of physical strength and posture issues) and cognition (difficulties with navigation) problems.

Table 2 The demographic characteristics of the participants

Participants	*Office 1*	*Office 2*	*Office 3*	*Total*
Number of participants	80	80	80	240
Gender				
Female	31	33	37	101
Male	49	47	43	139
Duration of employment				
More than 1 year	36	39	30	105
6–12 months	33	29	28	90
Fewer than 6 months	11	12	22	45
Duration of stay in the workspace in a typical week				
10 hours or fewer				
11–30 hours	54	42	51	147
More than 30 hours	24	30	23	77
	2	8	6	16
Type of work				
Administrative support	19	14	15	48
Professional	49	56	55	160
Managerial/supervisory	12	10	10	32

Results

Participants' ratings of the 46 items were analysed with the Statistical Package for the Social Sciences (SPSS). By means of the statistical analyses, frequency distributions, cross-tabulations and a chi-square test for independence were calculated. The alpha coefficient for all items was 0.8802, suggesting that they have relatively high internal consistency. The study also conducted an exploratory factor analysis to investigate correlated variables. Because a ratio as low as five subjects per variable is appropriate for distribution (Bentler and Chou 1987), the study sample size can be considered adequate in terms of sample representativeness and estimation accuracy. Through the Varimax method, a frequently used rotation option (Argyrous, 2005), a rotated component matrix was constructed to identify the number of factors among the set of correlations within the obtained data.

Refinement of the survey instrument

To carry out effective data analysis, items were eliminated based on two refinement factors: (i) floor and/or ceiling effects and (ii) strength of correlation scores. A floor and/or ceiling effect can occur if the response means for each item are lower and/or higher than they should be (Krathwohl, 1997). In the study, participants' responses were coded using a 'one' to 'five' scale: (1) 'Least important', (2) 'Less important', (3) 'Moderately important', (4) 'More important' and (5) 'Most important'. Items with a mean score lower than 1.50

and greater than 4.50 were deleted to eliminate the floor and ceiling effects. The survey frequency analysis indicated that survey item 40, relating to the importance of comfortable indoor air quality for better work performance, had a mean score of 4.71, and thus, it was excluded from additional data analyses. There were no mean scores lower than 1.50, so no items indicated a floor effect. The strength of the correlations among the survey items was calculated through exploratory factor analysis, which helps identify common issues and exclude unrelated ones. Pearson product-moment correlations of the response scores were calculated and a correlation matrix was constructed to investigate response items having a correlation score lower than 0.30; for a useful statistical approach a correlation coefficient of 1.00 indicates a perfect association between two variables, whereas correlation coefficients lowers than 0.30 are not preferred (Argyrous, 2005). In the current study, all correlations between item response scores were greater than 0.30.

Development of ergonomic factors for sustainable office systems

Based on Hogarty *et al*'s (2005) experiments, the study defined factor loadings in excess of 0.55 as suitable and excluded factors with factor loading values below 0.55. In this respect, factor analysis resulted in a six-factor solution that accounted for 64.301 percent variance, that is, 46 items had 64.301 percent of the variances in common, so they correlated highly with six common themes, and each theme was considered to be a factor scale (Table 3; see Appendix B for a detailed list of the six factors with their corresponding items and the factor loadings for each item under each factor). It should be noted that the factor loading of each item does not indicate the degree of importance. The six factor scales were derived regarding their correspondence to seven universal design principles: Principle 1: equitable use; Principle 2: flexibility in use; Principle 3: simple and intuitive use; Principle 4: perceptible information; Principle 5: tolerance for error; Principle 6: low physical effort; Principle 7: size and space for approach and use.

Factor 1 attends to the importance of indoor environmental quality, which is comprehensively composed of systems affecting the

Table 3 Developed six factor scales for a sustainable office environment

Factor	*Scale*	*Eigenvalue*	*Variance (%)*	*Cumulative (%)*
1	Comfortable indoor environmental quality	8.544	22.485	22.485
2	Intuitive wayfinding system	3.895	10.249	32.734
3	Flexibility and adaptability in use	3.178	8.362	41.096
4	Appropriate acoustic condition	2.281	6.002	47.098
5	User-adjustability in use	1.624	4.274	56.610
6	Adequate luminance level	1.385	3.645	64.301

user's perception of space, such as daylighting, humidity, temperature, ventilation and heating. Comfort for all regarding such systems is not only essential for human factors but also contributes positively to energy efficiency and cost savings. These systems do, however, require much in the way of product design, architecture and planning. Because older people are less active than younger people, they require more external heat to maintain their thermal balance (Collins and Hoinville, 1980). In this respect, heating, ventilation and air conditioning (HVAC) systems should be adapted to the workers and tasks performed. This factor also includes adequate daylighting, which is a critical element for natural ventilation and heating performance (Winchip, 2007) and maximizes visual comfort while reducing energy use.

Factor 2 is related to wayfinding and navigation. As Ho *et al* (2001) state, older adults are more likely than younger adults to misidentify a sign or miss a sign altogether. Thus, avoiding redundant signs and making signage and wayfinding intuitive is essential in sustainable development from the perspective of the human factors discipline. Clear space planning with colour coding, effective signage and landmarking helps make space legible not only for older employees, but for everyone. Moreover, consistency in meeting user expectations facilitates better work performance.

Factor 3 deals with flexible and adaptable systems that can accommodate future change and provide flexibility according to user preference. Considerations should be given to height-adjustable and comfortable furniture solutions, ergonomic chairs with options for sitting positions, sofas that can be easily transformed into day beds and easily movable wall partitions to provide space solutions when needed. Smart choices in this type of furniture would likely include items with long-lasting characteristics rather than items that must be continuously refurbishing to address changing user needs.

Factor 4 includes aspects related to acoustical comfort and sound quality and its clear transmission from one space to another. Because older workers have decreased hearing and localization abilities, non-work-related noise affects their concentration in open-office environments. 'When sound localisation ability is low, it affects a person's safe interaction with the environment' (Clarkson *et al*, 2007: 4–62). For these reasons, it is essential to provide office spaces that transmit speech with sufficient clarity, ensure sufficient loudness for ambient noise levels, and contemplate sound reflection and reverberation (Clarkson *et al*, 2007: 4–62).

Factor 5 deals with user control of lighting and HVAC systems. Many studies indicate that users prefer to be able to control aspects of their indoor environment (Galasiu and Veitch, 2006; Winchip, 2007). Thermostats, user-adjustable furniture systems and shading devices contribute positively to the sustainability of an office environment in terms of cost savings. However, because older workers are less likely to engage with such technologies, it is important to provide them with opportunities to experience and learn how to use them (Kaspar, 2004).

The final factor deals with artificial lighting quality in office environments. Lighting conditions should not disturb employees and glare should be eliminated. As people age, they are less adaptable to poor lighting conditions (Smith, 2008). In one study, although ‘there was no main effect of luminance, nor was there an interaction between age and luminance’ (Ho *et al*, 2001: 205); therefore, rather than providing average lighting quality, task lighting, photosensors and dimmable lights should be considered.

Exploration of qualitative data

Direct quotes obtained from the unstructured interviews from the survey are recorded in this section to provide evidence of the findings, underpin and illuminate the validity of the results. The responses are crucial in terms of older workers’ expectations and their contribution to designing sustainable offices. The responses were analysed in relation to the above factors from two perspectives: physical requirements (lighting and acoustics) and ergonomic requirements (general, furniture, ease of use, wayfinding and navigation).

Workers’ physical requirements are common and comparable for the three buildings in the study. Many expressed concerns regarding their hearing and vision capabilities. Similar expectations were found regarding noise levels, glare and daylighting. In general, older employees’ performance is enhanced by daylight. Most participants (60 of 80 in Office 1, 55 of 80 in Office 2 and 67 of 80 in Office 3) stated that a good balance between dark and light exposures is important. Daylighting is not only important in terms of perceiving colour and ensuring adequate luminance levels, but also regarding people’s view of and interaction with the outdoor environment. Of the participants, 200 (75 of 80 in Office 1, 59 of 80 in Office 2, and 66 of 80 in Office 3) identified that the presence of plants, external windows and fresh air stimulated their creativity. All the female participants noted that windows that open are their office’s best feature (101 of 240 participants). All participants complained about noise because of heavy road traffic (regardless of whether the windows were open or closed). The three offices are in Ankara’s city centre, and participants queried whether noise could be prevented from entering meeting (boardroom, cafeteria) spaces. A total of 50 of the 80 participants in Office 1, 41 of 80 in Office 2 and 32 of 80 in Office 3 (123 in total) stated that, for example, the tea area and the photocopy area should be separated from quieter work areas. All participants agreed that better space planning is essential for increased acoustical privacy. According to 182 participants (69 of 80 in Office 1, 53 of 80 in Office 2 and 60 of 80 in Office 3), phone calls and informal meetings are major barriers to productivity in an open-office layout.

> I feel more positive when there is daylight. (Participant 53)
>
> I am positively influenced when the work environment is connected with nature. (Participant 75)
>
> Although I prefer natural light, I have usually glare problems from windows. There should user-adjustable curtains or solar screens. (Participant 9)
>
> I struggle to hear well. Phone calls, conversations and laughing affect my concentration and performance. (Participant 120)
>
> There should be enough distance between adjacent workstations; otherwise I find background noise disruptive. (Participant 61)

Although ergonomic products (chairs, desks, workstations and computers (monitor, keyboard and mouse) are similar in the three offices, there are significant differences among user expectations and requirements because of employee variability in size, shape and gender. Seat height adjustability was the most important requirement in Office 2, whereas participants in Offices 1 and 3 found adjustable furniture only slightly important. In Office 1, 49 of 80 participants stated they want to access spaces with low physical effort and suggested eliminating stairs and level differences. In Office 3, 55 of 80 participants complained about overall discomfort and mentioned that they have work-related pain in their upper back, lower back and shoulders. They highlighted that providing ergonomic furniture may be beneficial, but perhaps not enough. Thus, firms should also consider encouraging regular exercise and breaks throughout the workday. Most female respondents (85 of 101) feel that safety and comfort are the most important satisfaction parameters in terms of ergonomic requirements because they have difficulty maintaining good posture and balance due to ageing. Moreover, all participants highlighted that controllable devices such as thermostats should provide clear instructions in larger print. In terms of thermal comfort, most of the participants (174 of 240) appreciate the ability to personally control the temperature, rather than being subject to an automated heating and cooling system. However, in Office 1, perceived temperature conditions barely affected performance, whereas people in Offices 2 and 3 found thermal comfort very important. This difference stems from workstation orientation; Office 1 faces north and Offices 2 and 3 face south. In terms of cognition, participants' expectations are similar among the three offices. Most (199 of 240) stated that they are less efficient in wayfinding and navigation because of age so that they prefer clear layouts and effective signage systems. They also highlighted the importance of colour that can help to cope with the fear of getting lost and disoriented.

> I have rheumatism; so I have difficulty using the stairs. Ease of access to the lifts is very important for me. (Participant 11)
>
> I am very satisfied with the adjustable seat height, but the controls are not simple or intuitive to use. (Participant 212)
>
> Because of musculoskeletal discomfort in my upper back, I need to move around during the working day. (Participant 187)
>
> I feel uncomfortable and my concentration level decreases if I am not satisfied with the indoor temperature. (Participant 23)
>
> To maintain a healthy atmosphere at work, thermal comfort is the most important thing. If the temperature is high and there is no ventilation, I get sleepy. (Participant 34)
>
> I get lost easily if there is no colour differentiation between floors. (Participant 55)
>
> Stairs, lifts and corridors should be easily visible. It helps with finding my way. (Participant 132)
>
> I would to see colour differentiation between floors. (Participant 57)

Discussion

The developed six factors in this study are generally in agreement with the studies mentioned in the literature review above. The next two subsections explore these factors in more detail and link them to the theoretical context to discuss their implications for practice from two points of view: (i) the ageing workforce and (ii) the sustainable development of office buildings.

Implications for the ageing workforce

From the perspective of the ageing workforce, several implications of this study can be used to design and construct ageing-friendly offices that promote health and facilitate productivity. First, the office environment should have an intuitive design that enables employees to use the spaces, furniture and environmental systems such as HVAC and lighting without prior knowledge of and experience with them. In some cases, this could be achieved through equipment with simply designed interfaces, and sometimes it necessitates architectural layouts or space allocations that do not interfere with users' routines. Because of changes in mental capacity, older workers generally experience reduced thinking speed and selective attention abilities, and are less able to process information (Smith, 2008). Through the potential benefits of intuitively designed offices, older workers' ergonomic and psychosocial needs can be better addressed.

The second implication from this study concerns a user's level of autonomy, which he or she should be able to control (Kobus *et al*, 2013). Although completely autonomous HVAC systems, for example, result in high energy efficiency and sustainable quality, to maintain and enhance productivity among older workers, considerable attention should be given to individuals' needs (adaptability and flexibility). Autonomy in an office environment means opportunities to control interactions with other users for privacy purposes and to be able to control environmental systems for comfort purposes. According to Anjum *et al* (2004), achieving privacy goals in an office environment indicates the right balance between addressing office design requirements and giving users control over their accessibility to others. According to Bluyssen (2010), achieving comfort goals in environmental systems is related to thermal comfort, lighting quality, acoustical quality and air quality. Control strategies can be performed to regulate heating, cooling and air conditioning, offer right variation on lighting intensity, prevent noise from entering a space and reduce pollution resources. All privacy and comfort requirements should correspond to individual needs and be adapted and controllable to the tasks performed.

Third, the office environment should provide older workers with adjustability, which is related more to the field of product design. Furniture specifications should explore higher levels of ergonomic comfort (Smith, 2008). The implications of achieving adjustability for older workers to fulfil their physical and cognitive requirements include designing furniture and office tools based on anthropometric studies. Because older workers' variability in size, shape, gender, age and education levels affect how they interact with an office environment more than younger workers' variabilities do, and anthropometric databases are not available for every user population (Nadadur and Parkinson, 2013), there are no common designs for the ageing workforce. Thus, ensuring adjustability results in increased costs, a situation that is not sustainable. To efficiently use resources, reduce costs and increase product lifetime, designers should consider optimally allocating adjustability and sizing methods as well as standardizing components and maintenance procedures.

Implications for the sustainable development of office buildings

From the perspective of sustainable office development, designers should take a broader sustainable system approach rather than focus on obtaining full points for each certification and achieving the highest energy, water consumption, indoor air quality and cost performance. This comprehensive approach should ensure that a building performs well both in terms of energy and workplace ergonomics (Hedge *et al*, 2010). Although the goals of ergonomics (efficiency, effectiveness, health, comfort, safety and usability) are closely aligned with the goals of sustainability (Thatcher, 2013), and both are concerned with improving the human environment, data supporting that sustainable environments are more favourable for occupants compared to conventional buildings are sparse (Hedge and Dorsey, 2013). In a LEED certified building, there can be high levels of satisfaction with air quality, but only moderate satisfaction with temperature and noise, and thus thermal discomfort could have an effect on workplace performance (Lee and Guerin, 2010). Therefore, based on the results of the current study, the first implication for sustainably developing office buildings should be creating a user-responsive office environment. This study defines the user-responsive office environment as one developed with an ergonomist's input that promotes effective and efficient use of systems, and achieves worker satisfaction with each sustainability feature. By feeling that their needs were considered in office space and system design, older workers (and all workers) become healthier and more productive. Office designs, sustainable or otherwise, that neglect workers' needs, demands and expectations are less likely to lead to productive and successful outcomes. A user-responsive building in terms of thermal comfort, noise, air quality and privacy can create positive emotions and results in terms of satisfaction and performance.

Based on qualitative exploration of the data in this study, one can also discuss its implications in terms of green ergonomics, defined as 'focus[ing] on the development of human systems that integrate fully in a sustainable way with natural environments' (Thatcher, 2013: 391). Nature should be integrated with office design. Green ergonomics also contributes to the success of this study's developed six factors. For comfortable indoor air quality, fresh air circulation and daylighting is important. External openings and windows that allow aesthetic views and maximize interaction with the natural environment positively influence illumination levels and intuitive wayfinding systems.

This study's third implication concerns the design process of sustainable office buildings. A user-centred process that engages users in all stages of design should be encouraged. This implication is also essential to overcome the communication gap between designers and older workers, noted in the introduction of this study. There is a strong relationship between user participation and system success in every stage of the development process (Iivari and Igbaria, 1997). The literature indicates various types of user participation methods: (i) observation and interviews as informative, (ii) task analysis, prototyping and usability evaluations as consultative and (iii) workshops, sketching, videotaping, brainstorming, scenario building and heuristic evaluation as active involvement (Damodaran, 1996). For best results, these methods should be applied during the earliest stages of the design process (concept, design, construction, occupancy), but can be applied at any stage. The current study focuses on a post-occupancy evaluation (POE), which is the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time (Preiser *et al*, 1988). This type of evaluation is a powerful tool that enables owners to determine the true value of a facility in terms of economic, environmental, human and community outcomes, information and results in the context of a built space's IEQ performance (Huizenga *et al*, 2002). The current study is a first stage in developing more appropriate design methodologies for sustainable offices; in future studies other types of participation could be applied.

Conclusion

This paper presents challenges between ageing workforces and sustainable development in office buildings. Although the results of the study and the data illuminate factors that can be found in any modern building, as Hedge and Dorsey (2013) state, 'it is important to continue to gather data on LEED buildings as related to their impact on occupants' health and performance, especially as LEED projects continue to significantly grow in number' (2013: 494). The three selected sustainable offices may provide better working conditions than conventional buildings, but the qualitative and quantitative data gathered from this study validate that for sustainability to truly meet its goals, the design process needs a holistic approach with user input.

Due to technological innovation and new concepts of working, contemporary offices are undergoing constant changes that have a large impact on all aspects of product design, architecture and planning (Anjum *et al*, 2005). Trends in office design point to a general shift towards more convenient, efficient, economical and sustainable working environments. It is important to focus on which holistic and ergonomic approaches require new concepts to improve employee's environmental satisfaction and job performance in those environments. However, most 'office environments have struggled to keep pace with what has been happening to organizations in terms of technology, business processes, customers and markets' (Turner and Myerson, 1998: 35) because human needs are not balanced. Offices have not been designed to take advantage of ergonomics; they may save energy, perform well and consume less water, but if they are not suitably designed for human capabilities, limitations and characteristics, they are unsustainable (Sev, 2009).

Having analysed the survey results, one can discuss the interdependence between factor scales for a user-responsive sustainable workspace (Figure 1). The appearance of six factor scales in the set of items indicates that achieving an ageing-friendly sustainable office environment necessitates considering each factor scale with its corresponding items. It is not enough to respond to only a few sets of factors and/or items and expect to achieve comfortable and productive workspaces; all factors are connected with each other. For example, based on the qualitative and quantitative data, for

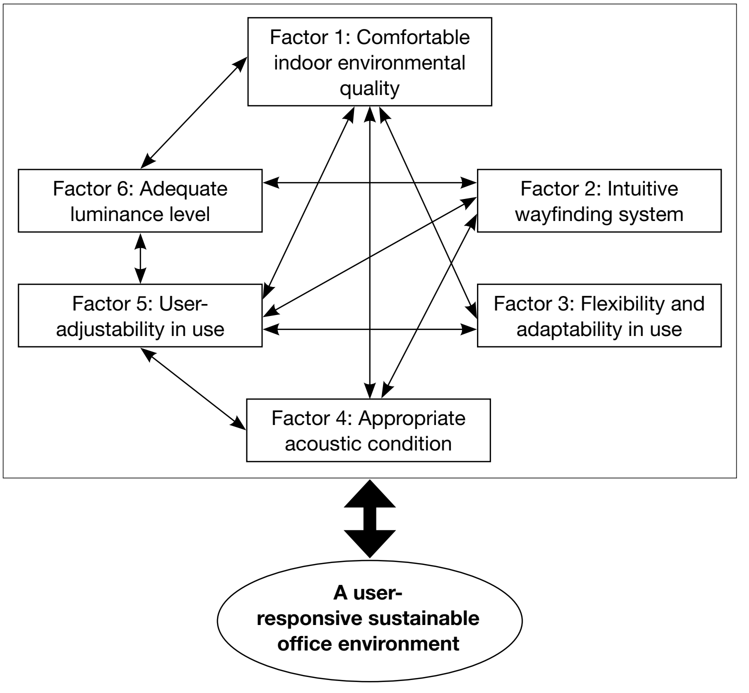

Figure 1
Interdependence between the factor scales.

Factor 1 (comfortable indoor environmental quality) adequate daylighting, flexible and adaptable use, clear sound transmission and user-controllable thermal systems, in addition to thermal comfort issues, affect occupants' performance and satisfaction. Factor 1 is thus directly related with Factor 3 (flexibility and adaptability in use), Factor 4 (appropriate acoustic condition), Factor 5 (user-adjustability in use) and Factor 6 (adequate luminance level).

Regarding Factor 2 (intuitive wayfinding system), intuitiveness highly depends on how adequately an interior space is naturally and artificially illuminated and how well the acoustic environment is adapted to the tasks being performed (because it is harder to concentrate in a noisy environment). Thus, Factor 2 is directly related with Factor 4 (appropriate acoustic condition) and Factor 6 (adequate luminance level). Considering the items of Factor 3 (flexibility and adaptability in use), it is not possible to ensure a flexible and adaptable office system without user adjustability, which is also a significant concern regarding the ability of indoor environmental quality to suit different people and various activities. Because user adjustability is a key concern for a sustainable office system, to achieve Factor 5 (user adjustability) all factors should be evaluated simultaneously or procedurally. In addition to the factors' parametric characteristics, each factor should focus on how to create interiors that are usable, healthy, satisfactory, safe, secure, simple and intuitive for all. Sustainable solutions should go hand in hand with a drive for a more user-centred design.

Eliciting older workers' needs and improving their comfort in a sustainable workspace enhance a building's energy efficiency and contribute to cost savings. 'Good ergonomics projects typically give a direct cost benefit of from 1 to 2, 1 to 10, with a typical payback period of 6–24 months' (Hendrick, 2008: 420). The developed factors help us understand that involving the ageing workforce in the design process and understanding their needs, expectations, demands and experiences with innovative building systems is beneficial to architects, designers, policy-makers and government bodies.

Although this study contributes new information to the literature, it has some limitations. No objective measures (temperature, humidity and noise level) of the three office environments were taken. The study was conducted in the Turkish context; future studies could compare other different cultural contexts. Table 4 lists some future

Table 4 Some future design research and application areas based on older workers' physical and ergonomic requirements

Physical requirements	
Indoor air quality	
	Designing simple thermal comfort control interfaces and interface locations (wall-mounted, remote control, computer screen).
Acoustic quality	
	Analysis on different acoustical conditions appropriate for older workers to reduce noise effects and improve acoustic privacy in open-plan offices.
	Development of more sustainable acoustic materials and research on their effects on acoustical qualities, such as the best materials to improve energy efficiency and help to transmit sound with sufficient clarity.
Adequate illumination	
	Development of various window types for enhanced daylighting quality and better work performance of older workers.
	The need for an-in-depth analysis on the degree of glare for older workers, and how the distance from windows and tasks affect it.
	Need of user-friendly lighting units for adequate illumination levels according to different indoor conditions and research to assess the trade-offs between access to view, glare control and lighting control for energy efficiency.
Ergonomic requirements	
	Development of computerized tools that could integrate ergonomic principles into the design process as early as possible.
	Analysis on the interdependence between task requirements, workspace components and sustainable building characteristics in terms of user satisfaction and work performance.
	Analysis on systematic comparisons between various wayfinding systems, such as colour coding, layout differentiation etc., and their impact on user cognition.

design research areas that emerged from this study's data through which to develop a user-responsive sustainable office environment based on older workers' physical and ergonomic requirements.

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Biography

Yasemin Afacan is Assistant Professor in the Department of Interior Architecture and Environmental Design, at Bilkent University, Ankara, Turkey. Following completion of her PhD on universal kitchen design in Bilkent University in 2008, she worked as a lecturer in Architecture in Queens University Belfast, UK. Her research is concerned with sustainability, aging, housing studies, CAD, inclusive design and architecture education. She teaches undergraduate-level courses on interior design and sustainable design for interiors. She has completed a project (founded by the Daiwa Anglo-Japanese Foundation) using post-occupancy evaluation to assess housing in Belfast, Northern Ireland and in Hamamatsu, Japan. Her works have appeared and presented in international refereed journals, conference proceedings, workshops and book chapters: such as *Applied Ergonomics, Journal of Engineering Design, Design Studies*, *Open House International*, including two book chapters in the *Designing Inclusive Futures and Systems* from Springer.

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Appendix A: The Survey Instrument

	Less important				*More important*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
A. Lighting quality					
1. Adequate daylighting in work areas.					
2. Adequate artificial lighting in work areas.					
3. Comfortable lighting quality in work areas.					
4. Adequate daylighting in circulation areas.					
5. Adequate artificial lighting in circulation areas.					
6. Comfortable lighting quality in circulation areas.					
7. Easy use of daylighting control systems, such as window shadings.					
8. Easy use of luminance level control systems.					
9. User-friendly solutions to glare and visual discomfort.					
B. Acoustical comfort					
10. Good quality of ambient acoustic environment in work areas.					
11. Good quality of ambient acoustic environment in circulation areas.					
12. Adequate noise control in work areas.					
13. Adequate noise control in circulation areas.					
14. Clarity of sound transmission in work areas.					
15. Clarity of sound transmission in circulation areas.					
16. Use of sound masking and sound conversion technologies.					
17. Adequate use of materials for sound blocking and reducing reverberation.					
C. Ergonomics					
18. Comfortable use of office furniture (chairs, desks, cabinets, storage spaces).					
19. Effective and efficient use of desk/work surfaces.					
20. Adequately clear floor area in circulation areas.					
21. Ergonomic chairs to different seating positions.					
22. Height-adjustable chairs.					
23. Simple and intuitive use of office system controls.					
24. Easily accessible storage spaces.					
25. Adequate storage space.					

	Less important				*More important*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
26. Flexible furniture solutions for changing user requirements.					
27. Flexible space solutions for changing user requirements.					
28. Adequate temporary collaborative workspaces.					
29. Adequate workstations for team workspaces.					
D. Wayfinding and navigation					
30. Arrangement of office layout consistent with user expectations.					
31. Easy navigation from one space to another.					
32. Simple and intuitive use of circulation systems.					
33. Efficient and effective use of colour coding.					
34. Efficient and effective use of signage systems.					
E. Indoor air quality					
35. Responsiveness of heating systems to changing user requirements.					
36. Responsiveness of cooling systems to changing user requirements.					
37. Responsiveness of mechanical ventilation systems to changing user requirements.					
38. Adequate natural ventilation provided through operational windows and doors.					
39. Homogenous temperature distribution between spaces.					
40. Comfortable indoor air quality for better work performance.					
F. Thermal comfort					
41. Adequate indoor thermal comfort during hot and moist summers.					
42. Adequate indoor thermal comfort during cold and dry winters.					
43. Adequate user-adjustable control systems, such as thermostats.					
44. Simple and intuitive use of control systems.					
45. Use of control systems with little force.					
46. Adequate overheating control systems on south and west facades.					

Appendix B: Developed Six Factor Scales for a Sustainable Office Environment

Factor 1: Comfortable indoor environmental quality

- Item 36: Responsiveness of cooling systems to changing user requirements (0.833).
- Item 35: Responsiveness of heating systems to changing user requirements (0.825).
- Item 38: Adequate natural ventilation provided through operational windows and doors (0.818).
- Item 37: Responsiveness of mechanical ventilation systems to changing user requirements (0.739).
- Item 1: Adequate daylighting in work areas (0.668).

Factor 2: Intuitive wayfinding system

- Item 31: Easy navigation from one space to another (0.870).
- Item 32: Simple and intuitive use of circulation systems (0.843).
- Item 30: Arrangement of office layout consistent with user expectations (0.753).
- Item 33: Efficient and effective use of colour coding (0.599).

Factor 3: Flexibility and adaptability in use

- Item 26: Flexible furniture solutions for changing user requirements (0.843).
- Item 27: Flexible space solutions for the changing user requirements (0.820).
- Item 23: Simple and intuitive use of office system controls (0.792).
- Item 28: Adequate temporary collaborative workspaces (0.710).
- Item 18: Comfortable use of office furniture (chairs, desks, cabinets, storage spaces) (0.610).
- Item 21: Ergonomic chairs to different seating positions (0.599).

Factor 4: Appropriate acoustic condition

- Item 13: Adequate noise control in circulation areas (0.883).
- Item 10: Good quality of ambient acoustic environment in work areas (0.856).
- Item 15: Clarity of sound transmission in circulation areas (0.704).
- Item 16: Use of sound masking and sound conversion technologies (0.631).

Factor 5: User-adjustability in use

- Item 7: Easy use of daylighting control systems, such as window shadings (0.691).
- Item 43: Adequate user-adjustable control systems, such as thermostats (0.600).
- Item 44: Simple and intuitive use of control systems (0.590).

Factor 6: Adequate luminance level

- Item 2: Adequate artificial lighting in work areas (0.821)
- Item 5: Adequate artificial lighting in circulation areas (0.598).
- Item 8: Easy use of luminance level control systems (0595).