Physical characteristics of the indoor environment that affect health and wellbeing in healthcare facilities: a review

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REVIEW ARTICLE

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Understanding the physical characteristics of the indoor environment that affect human health and wellbeing is the key requirement underpinning the beneficial design of a healthcare facility (HCF). We reviewed and summarized physical factors of the indoor environment reported to affect human health and wellbeing in HCFs. Altogether, 214 publications were selected for this review. According to the literature, there is strong scientific evidence to show that following indoor environmental factors have beneficial effects for all user groups when appropriately designed or implemented: the acoustic environment, ventilation and air conditioning systems, the thermal environment, the visual environment (e.g. lighting, and views of nature), ergonomic conditions and furniture. In contrast, the effect of special layouts and room type and floor coverings may be beneficial for one group and detrimental for another. Some of the physical factors may, in themselves, directly promote or hinder health and wellbeing, but the factors can also have numerous indirect impacts by influencing the behaviour, actions and interactions of patients, their families and the staff members. The findings of this research enable a good understanding of the different physical factors of the indoor environment on health and wellbeing and provide a practical resource for those responsible for the design and operation of the facilities as well as researchers investigating these factors. However, more studies are needed in order to inform the design of optimally beneficial indoor environments in HCFs for all user groups.

Keywords: health; healthcare facility; patient; physical environment; staff; wellbeing

Introduction

It has long been known that the physical environment of a healthcare facility (HCF) can affect patients and staff. In the late nineteenth century, Florence Nightingale suggested that patients would recover more quickly if they were cared for in an environment that had natural light, ventilation, cleanliness and basic sanitation (Nightingale 1860, 1893). However, HCFs are often considered starkly institutional, unacceptably stressful, and unsuited to the emotional needs of...
patients, their families and healthcare personnel (Ulrich 1991; Horsburgh 1995). As a growing body of research has proven that the physical built healthcare environment has an impact on the health and wellbeing of patients and staff, there has been growing awareness among healthcare administrators and medical professionals of the need to create a healing, ‘psychologically supportive’ environment that supports wellbeing and helps patients cope with the stress that accompanies illness (Ulrich 2000; Stichler 2001; Ulrich et al. 2004, 2008; Dijkstra, Pieterse, and Pruyn 2006; Ampt, Harris, and Maxwell 2008; Dijkstra, Pieterse, and Pruyn 2008).

Many HCFs are adopting elements of evidence-based design (EBD) in recent construction, expansion or remodelling activities. According to the Center for Health Design (Goetz et al. 2010), EBD is the process of basing decisions regarding the built environment on credible research to achieve the best possible outcomes. EBD is a process used by architects, interior designers, facility managers and others involved in the planning, design and construction of commercial buildings (Goetz et al. 2010; Carr 2012). Properly implemented EBD – which includes physical healthcare environmental factors as important elements – can improve patient safety (reducing hospital-acquired infections and medical errors) and outcomes (reducing pain, improving sleep, reducing stress and depression), reduce spatial disorientation, improve patient privacy and confidentiality (fostering social support) and improve staff outcomes (decreasing stress and increasing effectiveness) (Ulrich et al. 2004; Carr 2012) and job satisfaction of the staff, affecting work performance, productivity and ultimately the quality of healthcare (Lundstrom et al. 2002; Tanja-Dijkstra and Pieterse 2010).

In order to design, build and adapt beneficial indoor environments in an HCF, we must first understand the physical characteristics that are most likely to optimize individual physical, mental and emotional wellbeing. Although previously published studies give relevant information, they tend to deal with individual factors rather than a more integrated assessment of the total indoor environment. Therefore, the aim of this study was to critically review and summarize physical factors of the indoor environment reported to affect human health and wellbeing in HCFs. Through this, we sought to provide a practical resource for those responsible for the design and operation of the facilities, as well as for healthcare managers, professionals and indoor environment researchers investigating these factors.

It should be noted, however, that reviewing quantitative information or the recommended values of physical factors (from published standards and guidelines) was beyond the scope of this work, and therefore, numerical guidelines are only briefly mentioned in the sections on the acoustic environment and thermal environments.

Materials and search methods

Literature search

A PubMed search of the literature published from 1 January 1975 through 10 August 2012 was performed. The following search terms were used: ‘environment’, ‘physical’, ‘interior’, ‘indoor’, ‘design’, ‘feature’, ‘factor’, ‘health effects’, ‘health’, ‘wellbeing’, ‘healing environment’, ‘restorative’, ‘healthcare facility’, ‘healthcare space’, ‘staff’, ‘patient’, ‘visitor’, ‘medical outcomes’, ‘outcomes’, ‘health promotion’, and ‘hospital’. One or more following search terms were used in every combination: ‘healthcare’, ‘facility’, ‘facilities’, ‘healthcare space’ and/or ‘hospital’. Following this, the reference lists were searched for interesting articles, based on their titles and abstracts with emphasis on the health outcomes of physical factors of the indoor environment in an HCF (e.g. a hospital) on patients and staff. After this, the most interesting papers were chosen for a more accurate search. We also added a few relevant (often cited) authors as search terms (Ulrich, R.S.; Joseph, A.; Cooper-Marcus, C.; and Devlin and Arneill). In addition, we manually searched in Google for
guidelines (given by AIA and FGI, ANSI/ASHRAE, World Health Organization (WHO), CDC/HICPAC, Institute of Medicine (IOM), and the National Institute of Building Sciences) and relevant sections of books, bibliographies and monographs. In order to find relevant guidelines and sections of books, we also personally contacted experts in the field of study.

The search was undertaken from February 2011 through August 2012. The search terms for this literature review are reasonably broad, so articles concentrating on very specific and detailed areas of hospital design and its effects may not have been included.

**Literature selection**

All the references that were identified were initially selected on the basis of their titles and/or abstracts, with emphasis on the health outcomes of physical factors of an HCF (e.g. a hospital) on patients and staff.

Emphasis was given to the reporting of empirical studies from peer-reviewed journals. Full reports from potentially relevant publications were obtained and checked for competence for inclusion in this review. Decisions about whether to include publications were based on the completeness of the study. Limiters were set for the English language and for publications that were electronically available either through a QUT or FIOH library subscription or free download from the Internet. Inclusion criteria specified HCFs/hospitals in western countries.

Altogether 605 abstracts (the selection of abstracts was based on the eligibility of the study according to the title) were read; following this, 315 full publications were read (the selection of full publications was based on the eligibility of the study according to the abstract); and then, after the evaluation, 214 publications (148 journal articles and 66 other publications (books/book sections, conference papers, dissertations and reports)) were included in this review article. About 5% of the selected material was published before 1980, 23% during 1980–1999, 68% during 2000–2010 and 4% after 2010.

**Key findings and discussion**

The key findings and critical discussion relating to each physical factor within the indoor environment that affects health and wellbeing in HCFs are presented under separate subtitles below. The most beneficial physical factors and their outcomes (including possible detrimental effects) are summarized in Table 1. In addition, more detailed information on the effects of different physical factors on patients and staff is provided in Table 1S in the Supplementary material of this article (available online).

As shown in Table 1, there is strong scientific evidence to show that the following indoor environmental factors have beneficial effects for all user groups when appropriately designed or implemented: the acoustic environment, ventilation and air conditioning systems, the thermal environment, the visual environment (e.g. lighting and views of nature), ergonomic conditions and furniture. In contrast, the effect of special layouts and room type and floor coverings may be beneficial for one group and detrimental for another.

**Spatial layout and room type**

Several studies have reported that the basic layout of the HCF ward affects patients as well as staff (Hendrich 2003; IOM 2004; Ampt, Harris, and Maxwell 2008). Decentralized nursing stations reduce the amount of walking undertaken by the nursing staff (Sturdavant 1960; Trites and Green 1970; Shepley 2002), and thus increase patient care time (which e.g. increase the patients’ safety and social support from staff to patients) (Hendrich 2003; IOM 2004; Reiling et al. 2004; Ampt, Harris, and Maxwell 2008). However, nurses working in decentralized units can feel
Table 1. Summary of beneficial physical factors within the indoor environment and their outcomes (including possible detrimental effects) in HCFs.

<table>
<thead>
<tr>
<th>Environmental characteristic/physical factor</th>
<th>Beneficial&lt;sup&gt;a&lt;/sup&gt; effects on patients</th>
<th>Beneficial&lt;sup&gt;a&lt;/sup&gt; effects on staff</th>
<th>Detrimental&lt;sup&gt;b&lt;/sup&gt; effects on patients</th>
<th>Detrimental&lt;sup&gt;b&lt;/sup&gt; effects on staff</th>
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<tr>
<td>Spatial layout and room type</td>
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<tr>
<td>Decentralized nursing stations</td>
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<td>Centralized nursing stations</td>
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<td>Single-patient rooms</td>
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<td>Areas for family</td>
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<td>Areas for staff</td>
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<tr>
<td>Floor covering and surfaces</td>
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<td>Carpeting</td>
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<td>Acoustic environment</td>
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<td>Noise reducing finishes (e.g. high performance sound absorbing ceiling tiles)</td>
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<td>Ventilation and air conditioning</td>
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<td>A properly functioning and efficient ventilation system (mechanical or natural)</td>
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<td>Heating, Ventilation Air Conditioning system in the isolation room</td>
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<td>High-Efficiency Particulate Air filters in the isolation room</td>
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<td>Thermal environment</td>
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<td>Thermal comfort</td>
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<td>Visual environment</td>
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<td>Appropriate lighting</td>
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<td>Daylight</td>
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<td>Bright artificial light</td>
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<td>Control over lighting (individual switches)</td>
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<td>Views of nature</td>
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<td>Well-designed gardens (which provide calming and pleasant views of nature, foster access to social support and privacy, and provide opportunities for escape from stressful clinical settings)</td>
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<td>Patients’ free access to secure gardens/outdoor environments</td>
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<td>Plants in the patient room</td>
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<td>Positive art (e.g. realistic art depicting serene natural environments)</td>
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<td>Ergonomic conditions and furniture</td>
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<td>Ergonomic conditions (e.g. ergonomic work tools: ceiling lifts, electrical beds and shower trolleys)</td>
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<tr>
<td>Appropriate furniture design and covering</td>
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<td>(attractive, non-institutional, safe and comfortable for all users, made using easily cleaned and sound-absorbing materials)</td>
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<td>Appropriate furniture arrangements</td>
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<td>(configurable furniture supporting acoustic and visual privacy)</td>
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(Continued)
isolated from their colleagues, lose their sense of team connection (Tyson, Lambert, and Beattie 2002), and have fewer social interactions compared with nurses working in centralized nursing stations (Zborowsky et al. 2010).

The single-bed patient room

There are a large number of studies and guidelines that recommend the provision of single-patient rooms (Ulrich et al. 2004; AIA and FGI 2006; van de Glind, de Roode, and Goossensen 2007; Joseph 2007; Ampt, Harris, and Maxwell 2008; Ulrich et al. 2008). The reported advantages and beneficial effects of having a single-patient room over a double room or multi-bed unit in HCFs are presented in Table 2.

Although there is strong scientific evidence (similar findings from multiple rigorous studies) indicating that a single-patient room improves healthcare outcomes, there are also unintended consequences of single rooms, including the lack of social/emotional support from a roommate (Joseph 2007; Ulrich 2000), decreased visibility of patients by staff (Brown and Taquino 2001), and less staff interaction (Ampt, Harris, and Maxwell 2008). However, in most cases, the benefits outlined above tend to outweigh these disadvantages. For example, the presence of a roommate is more often a source of stress, for example by causing loss of privacy, being seriously ill or unfriendly, or having too many visitors (Ulrich et al. 2004, 2008).

Family areas

Provision of an area (‘family zone’ in a separate room or within a single-patient room) where patients and their families/visitors can be together and where family can sleep overnight are recommended in several publications (Douglas and Douglas 2004; Johnson and Abraham 2004; Joseph 2006c; Kutash and Northrop 2007; Carr 2011). The provision of this kind of area is reported to enhance social interaction and increase support from family and visitors (Douglas and Douglas 2004; Johnson and Abraham 2004; Joseph 2006c; Kutash and Northrop 2007; Ulrich et al. 2008; Carr 2011), as well as reduce patient falls, since family members can assist patients with getting in and out of bed (Ulrich et al. 2008). However, providing additional areas where patients can reside may make it more difficult for the staff to observe patients, and this can be problematic in some types of facility units, such as a psychiatric units (Tyson, Lambert, and Beattie 2002). Family areas may also not be appropriate for patients with infectious conditions, or conversely, for those who are highly susceptible to infection.
Several studies recommend the provision of areas for healthcare staff to relax, replenish, network and communicate with colleagues (Johnson and Abraham 2004; Dalke et al. 2006; Joseph 2006c; Ampt, Harris, and Maxwell 2008). By promoting staff communication, information sharing and teamwork can be promoted, which is believed to affect safety and to provide more effective healthcare service (Joseph 2006c).

**Floor coverings**

Material selection may affect patient wellbeing and comfort. For example, the benefits offered by different types of flooring materials, such as carpet and hard or glossy materials (including vinyl...
and linoleum), are worthy of consideration (Ulrich 2000). Appropriate floor coverings, other surface materials and their frequent cleaning have a key role in minimizing nosocomial infections in HCFs. Several studies have demonstrated that larger amounts of dust accumulated on porous materials, such as carpeted floors, than on smooth floors (Gravesen et al. 1986; Thatcher and Layton 1995; Leese et al. 1997), and some studies report that a carpet is more difficult to clean than hard floor coverings (Harris 2000), with bacteria returning to pre-cleaning levels fairly quickly (Joseph 2006b). In addition, occupant activities, such as heavy and fast walking, can re-suspend more dust from carpets than from equally loaded hard floors (Qian and Ferro 2007).

Opposite results showed that carpets performed well in cleaning (Lankford et al. 2006), and certain serious pathogens survive for a shorter time on carpets than on other floor coverings (including linoleum, rubber tile, vinyl composition tile and vinyl sheet goods), and carpeting transferred less pathogens to the hands via contact vinyl or rubber flooring (Lankford et al. 2006). The other reported advantages of using carpets include noise reduction (Willmott 1986; Counsell et al. 2000; Harris 2000; Joseph 2006b, 2006c), glare reduction (Carpman and Grant 1993; Horton 1997; Harris 2000), ease of walking, a probable reduction in falls and resultant injuries, a feeling of safety (Willmott 1986; Counsell et al. 2000; Harris 2000; Joseph 2006b), improved personal comfort (psychological and thermal comfort) (Weinhold 1988; Radke 1997), longer visits by family and friends, increased social support (Harris 2000), and a more homelike (non-institutional) ambience (Cheek, Maxwell, and Weisman 1971; Glod et al. 1994).

The reported disadvantages of carpets (other than being more difficult to keep clean than hard flooring) include: carpets provide a supportive environment for the growth of fungi and bacteria (Anderson et al. 1982; Skoutelis et al. 1994; Beyer and Belsito 2000; Joseph 2006b); and it can be difficult for staff to push carts, gurneys and wheelchairs down carpeted hallways (Harris 2000) (which has been associated with an increased risk of neck, shoulder and lower back pain (Hoozemans et al. 2002; Smedley et al. 2003)).

In conclusion, there are both reported advantages and disadvantages of using carpet in HCFs. CDC/HICPAC guidelines (Sehulster et al. 2004) suggest that carpeting should be avoided in areas where spills are likely to occur or when patients are at greater risk of airborne infections.

Acoustic environment (noise reduction)

There are numerous noise sources in HCFs (Jastremski 2000; Bremmer, Byers, and Kiehl 2003; Ulrich et al. 2004; Beyea 2007), and noise levels in most hospitals far exceed recommended guidelines given by the Environmental Protection Agency (maximum noise levels of 40 dB(A)) and WHO (maximum levels of 30—40 dB(A) in patients’ rooms at night) (Busch-Vishniac et al. 2005; Johns Hopkins University 2005; Johnson and Tornhill 2006; Kracht, Busch-Vishniac, and West 2007; WHO 2007; Solet et al. 2010).

Among patients, noise is one of the features of the ambient environment that patients complain about most frequently (Ulrich et al. 2008). Studies have found that among patients, reduced noise levels (e.g. by using noise-reducing finishes such as high-performance sound-absorbing ceiling tiles or by using architectural features such as single-bed patient rooms and short corridors (Joseph and Ulrich 2007; Ulrich et al. 2008)) improve sleep, reduce annoyance, improve satisfaction, reduce both pain and the use of pain medications, decrease psychological and physiological stress, reduce emotional exhaustion, reduce headaches, promote better communication between patients and family members, enhance patient privacy and confidentiality, improve safety (reduce medical errors committed by staff), decrease heart and respiratory rates, decrease blood pressure, increase oxygen saturation, decrease confusion and disorientation, shorten recovery time and hospital stays, and reduce re-hospitalization (Hilton 1985; Evans and Cohen 1987; Yinnon et al. 1992; Grumet 1993; Biley 1994; Bayo, Garcia, Garcia 1995;

Although there has been limited research on the effects of noise on healthcare staff, noise is recognized as a distraction and stressor for staff. Among staff, reduced noise levels in HCFs have been associated with reduced stress, reduced emotional exhaustion and burnout, reduced fatigue, increased satisfaction, increased effectiveness, increased productivity (Biley 1994; Bayo, Garcia, and Garcia 1995; Sanderson et al. 2005; Zun and Downey 2005; Beyea 2007; Joseph 2007; Ulrich et al. 2008) and improved communication and decreased medical errors (Flynn et al. 1999; Zun and Downey 2005; Joseph and Ulrich 2007). In addition, improved acoustical conditions have been linked to a reduction in work demands experienced by staff, as well as reported pressure and strain (Blomkvist et al. 2005).

**Ventilation and air conditioning systems**

Properly functioning and efficient ventilation systems are key for ensuring the good indoor air quality (Spengler, Samet, and McCarthy 2001), and they can have a significant influence on the incidence of respiratory disease, symptoms of allergies and asthma, the transmission of infectious diseases, chemical sensitivity and worker productivity (Fisk 2001; Joseph 2006b, 2007).

In HCFs, the Heating, Ventilation Air Conditioning system is fundamental to maintain negative pressure within isolation rooms, to protect the health of workers, patients and visitors, as well as to control patients’ risk for airborne diseases (Tang et al. 2006; CDC and HICPAC 2007; Li et al. 2007; Eames et al. 2009; Tunga et al. 2009; Zhao et al. 2009; Balocco and Liò 2010). However, there is insufficient scientific evidence for recommending a minimum outdoor ventilation rate for infection control (Li et al. 2007).

Exposure reduction through the use of High-Efficiency Particulate Air (HEPA) filters in isolated rooms has been the preferred primary preventive strategy for high-risk patients (Abdul Salam et al. 2010). Several recent studies reported that HEPA filters significantly reduce the risk of Aspergillus infection (Withington et al. 1998; Hahn et al. 2002; McCann et al. 2004; Eckmanns, Ruden, and Gastmeier 2006), as well as the airborne concentrations and/or infection rates for a wide range of other aerosolized pathogens (Rutala et al. 1995; Loo et al. 1996; Dee et al. 2006).

Given that natural ventilation is often considered to be economical, and published results and guidelines suggest the efficacy of natural ventilation in diluting any airborne pollutants and the infectious airborne pathogens (Escombe et al. 2007; WHO 2009; Qian et al. 2010), natural ventilation has recently been proposed as an environmental measure to reduce the risk of airborne infection spread in HCFs (WHO 2009; Qian et al. 2010). However, there is still a need for more epidemiological studies to support the use of natural ventilation for infection control. Natural ventilation also has some significant disadvantages that need to be taken into consideration when making decisions about ventilation type. For example, natural ventilation does not allow for negative pressure in isolation areas, it is easily affected by outdoor climate and/or occupant behaviour, and it is unsuitable in many climates (WHO 2009).

**Thermal environment**

There has been growing scientific evidence for the influence of the thermal environment (thermal comfort) on wellbeing in HCFs (Hwang et al. 2007; Wu 2011). According to ASHRAE Standard 55-2010, thermal comfort is ‘that condition of mind which expresses satisfaction with the thermal environment’ (ASHRAE 2010). For example, the CIBSE (2005) standard provides
recommendations for acceptable night-time temperatures in HCFs. According to that standard, bedroom temperatures at night should not exceed 26°C unless ceiling fans are available (CIBSE 2005).

Among patients, thermal comfort has been associated with stabilized moods, improved sleep quality and quantity, and reduced length of stay in hospitals (Hwang et al. 2007). Too warm a night-time temperature was reported to reduce total sleep owing to increased wakefulness (Parmeggiani 1987; Okamoto-Mizuno, Tsuzuki, and Mizuno 2004). Correspondingly, it has been reported that in cold environments, patients had difficulty getting to sleep and staying asleep (Okamoto-Mizuno, Tsuzuki, and Mizuno 2005). When air conditioning is used to cool the air, cool draughts can make the environment unpleasant (Bradshaw 2006) for both patients and staff.

Among staff, thermal comfort has been associated with improved work performance and productivity (Mackworth 1950, Ramsey and Kwon 1988; Kaplow and Hardin 2007) as well as decreased stress and anxiety (Wyon, Lidwell, and Williams 1968). In addition, given that healthcare professionals are required to perform numerous complex tasks, thermal stress and discomfort have the potential to lead to increases in errors and irritability and they have a detrimental effect on patient care (Wu 2011).

There are large variations, both physiologically and psychologically, from person to person (ASHRAE 2010); thus, the environmental conditions required for thermal comfort are not the same for everyone and it is difficult to satisfy everyone in a given space (ASHRAE 2010). Different user groups within the same hospital environment may prefer different temperatures for comfort because of different activity and acuity levels, age, clothing and length of stay in the ward (Hwang et al. 2007; Wong et al. 2009; Wu 2011). For example, the patients staying in the ward for longer periods of time, whether confined to bed or ambulant, will generally be involved in a minimum of activity and are likely to prefer or tolerate higher temperatures than other user groups (Legg 1971). Among medical and nursing staff, those who may be working physically hard (e.g. carrying patients) may have different preferred thermal conditions than those doing tasks involving little physical exertion (e.g. medical inspections) (Wu 2011).

**Visual environment**

*Lighting (natural daylight and artificial light)*

Sufficient and controllable lighting is beneficial for both patients and staff (Ulrich 2000; Edwards and Torcellini 2002; Joseph 2006a; Joseph 2007; Ampt, Harris, and Maxwell 2008; Ulrich et al. 2008). Although natural daylight via windows is generally preferred over artificial lighting (Devlin and Arneill 2003), artificial lighting is still necessary in HCFs.

Among patients, daylight improves circadian rhythms by affecting melatonin production and regulation, and has a positive affect on vitamin D metabolism (McColl and Veitch 2001; Figueiro et al. 2006; Joseph 2006a; Ampt, Harris, and Maxwell 2008), improves sleep, reduces stress (Ulrich et al. 2008), alleviates pain and reduces the use of pain medications and analgesic medication (Walch et al. 2005; Dijkstra, Pieterse, and Pruyn 2006; Joseph 2006a; Ampt, Harris, and Maxwell 2008; Ulrich et al. 2008), increases feelings of openness and freedom (Edwards and Torcellini 2002), improves mood and reduces incidence of depression (Edwards and Torcellini 2002; Ulrich et al. 2004, 2008; Dijkstra, Pieterse, and Pruyn 2006; Joseph 2006a; Lorenz 2007), reduces agitation levels for patients with Alzheimer’s disease (Joseph 2006a; Ampt, Harris, and Maxwell 2008), increases patient satisfaction (Ulrich et al. 2008), and increases vision for the elderly (Edwards and Torcellini 2002). In addition, for certain types of patients, daylight has been associated with improved recovery rates and a reduced length of stay (Küller and

Among staff, daylight has been associated with reduced stress (Alimoglu and Donmez 2005; Joseph 2006a; Ulrich et al. 2008), improved performance and reduced errors (Ulrich et al. 2004; Cohen and Smetzer 2009), reduced absenteeism, increased positive attitudes, improved mood, reduced depression, enhanced morale, reduced fatigue, reduced eyestrain (Robbins 1986; Edwards and Torcellini 2002), improved job satisfaction (Mroczek et al. 2005; Joseph 2006a; Ulrich et al. 2008), reduced desires to quit and improved general wellbeing (Leather et al. 1998; Joseph 2006a; Ampt, Harris, and Maxwell 2008). In addition, daylight provides contact with the outside living environment and meets the visual needs of both patients and staff (Robbins 1986; Edwards and Torcellini 2002).

Although it is believed that artificial light can cause visual fatigue and headaches (Altimier 2004), exposure to bright artificial light has been reported to be effective in elevating mood in depressed patients (Dijkstra, Pieterse, and Pruyn 2006; Joseph 2006a; Lorenz 2007; Ulrich et al. 2008). For staff, bright lighting for work surfaces and in areas where staff perform critical tasks significantly lowers the rate of medication-dispensing errors and thus increases patient safety (Buchanan et al. 1991; Ulrich et al. 2008). However, it is important to note that in counseling rooms, people feel more comfortable talking, and they talk longer, with dim lighting as opposed to bright lighting (Ulrich et al. 2008).

Improved lighting reduces falls and allows the elderly to function more independently by improving social contact, appetite, mood, self-confidence and anxiety levels (Edwards and Torcellini 2002). For people with failing vision, improved lighting raises their confidence during many simple activities (Edwards and Torcellini 2002). Although a constant level of light intensity has been associated with improvement in alertness for shift workers as well as improvement in agitation in patients with Alzheimer’s disease (Ulrich et al. 2004; Joseph 2006a), prolonged exposure to high-intensity lighting has been associated with losing a major stimulus for maintaining normal 24-hour functioning (Joseph 2006a). Thus, it is important to recognize the effects of the amount and timing of light on different user groups.

Having control over lighting (individual switches) provides beneficial effects for both patients and staff (Devlin and Arneill 2003; Dalke et al. 2006; Ampt, Harris, and Maxwell 2008) because it adds to a feeling of normality. It has also been reported that a lack of control over lighting can increase depression, passivity, blood pressure and reduce immune function, and was considered as a source of additional stress for already stressed patients (Devlin and Arneill 2003).

There is a need for further research to study further the comparative impact of daylight and artificial light on staff mood and work performance, and provide deeper knowledge about the importance of light as one healing element in the indoor environment design of HCFs.

**Views, exposure and access to nature**

In healthcare settings, views of nature and exposure and access to nature provide beneficial effects for patients and their families, as well as for staff (Cooper-Marcus and Barnes 1995; Ulrich 1999; Whitehouse et al. 2001; Douglas and Douglas 2004; Sherman et al. 2005; Curtis et al. 2007; Ulrich et al. 2008). Among patients, window views of nature have been associated with reduced levels of the following outcomes: stress, anxiety, delirium, depression (Wilson 1972; Parker and Hodge 1976; Keep, James, and Inman 1980; Ulrich and Gilpin 2003; Ulrich et al. 2008), pain, need for strong pain medications (Ulrich 1984b, 1993; Ulrich et al. 2008), blood pressure, heart rates (Ulrich and Gilpin 2003), (shorter) postoperative hospital stays (Ulrich 1984a), complications (Ulrich 1984b), post-surgical delirium reactions (Ampt, Harris, and
Maxwell 2008), sleep disturbance, visual disturbance and hallucinations (Ampt, Harris, and Maxwell 2008). Views of nature have been also associated with increased/improved (faster) recovery (Ulrich 1984b, 1984a), orientation to the time of day (Joseph 2007; Ampt, Harris, and Maxwell 2008), distraction (Joseph 2007), satisfaction with nursing care (Ulrich 1984a; Ulrich et al. 2008), and emotional wellbeing (Ulrich 1984a). In addition, a window view to the outside world adds to a sense of normalcy for patients (Ampt, Harris, and Maxwell 2008) and has a positive influence on patient hospitalization (Devlin and Arneill 2003).

For staff, views of nature reduce stress (Leather et al. 1998; Ampt, Harris, and Maxwell 2008; Ulrich et al. 2008), improve performance and productivity, increase job satisfaction (Kaplan 1992; Clay 2001; Ulrich et al. 2008), improve concentration (van den Berg, Hartig, and Staats 2007), reduce headaches (Kaplan 1992), reduce job pressure (Kaplan 1992), and offer a restorative effect after performing demanding processes (Kaplan and Kaplan 1989).

Scientific evidence strongly suggests that gardens, which provide calming and pleasant views of nature, foster access to social support and privacy, and provide opportunities for escape from stressful clinical settings, and are effective and beneficial settings for fostering restoration among stressed patients, family members and staff (Cooper-Marcus and Barnes 1995; Ulrich 1999; Whitehouse et al. 2001). It has also been reported that significant physiological restoration is manifested with as little as three to five minutes of exposure, or even less (Ulrich 1981, 1991; Hartig et al. 2003; Laumann, Gärling, and Stormark 2003; Ulrich and Gilpin 2003; Joye 2007). In addition, the presence of gardens in healthcare settings improves mood and increases satisfaction among all users (Cooper-Marcus and Barnes 1995, 1999; Sadler 2001; Whitehouse et al. 2001).

Patients appreciate and desire access to gardens (Douglas and Douglas 2004; Curtis et al. 2007). For psychogeriatric patients who are permitted go into the garden on their own free will, the access to gardens decreased both verbal and physical aggression as well as nurse-initiated medication (McMinn and Hinton 2000). For patients with Alzheimer’s disease, access to secure outdoor environments has been reported to decrease violent behaviour (Mooney and Nicell 1992; Namazi and Johnson 1992).

Exposure to nature, in order to reduce patients stress and expedite their recovery, can also be provided by bringing natural elements, such as plants, into HCFs (Dijkstra, Pieterse, and Pruyn 2008). Dijkstra, Pieterse, and Pruyn (2008) suggested that the perceived attractiveness of a room may be an explanation for the stress-reducing effects of plants. It has been suggested that exposure to indoor plants increases pain tolerance (Lohr and Pearson-Mims 2000) and improves pain control among patients (Diette et al. 2003), as well as improving staff wellbeing (Fjeld 2002).

Despite the proven benefits of indoor plants, there are some patient areas in hospital environments where plants and flowers are not recommended. According to the CDC and HICPAC Guidelines, flowers and plants should be excluded from areas where immunosuppressed patients are located (e.g. hematopoietic stem cell transplant [HSCT] units) (CDC and HICPAC 2003). More studies are needed concerning the health benefits that indoor plants have on the wellbeing of patients and staff in the HCFs, as studies so far seem to be more focused on health risks (LaCharity and McClure 2003).

**Colour**

Colour has been described as a subjective visual sensation produced by light, and the perception of colour depends on the colour makeup of the light, the surface material and the age and health of the viewer’s eyes (Crone 1999; Steffy 2002; Tofle et al. 2004). In the literature, colours are linked to physiological, psychological and social reactions of human beings (Tofle et al. 2003). There is general consensus that warmer colours tend to activate, stimulate and energise, while cooler colours are more calming and relaxing (Ampt, Harris, and Maxwell 2008). For hospital design,
perhaps the most important finding is the existence of an association between certain colours and particular moods or emotions (Fehrman and Fehrman 2004; Tofle et al. 2004).

However, it is important to note that while many of the recent studies that focus on psychological, physiological and behavioural responses are scientifically rigorous, the findings are often based on an extremely limited range of colour samples and/or a small sample group (Tofle et al. 2004; O’Connor 2011). There is no evidence to suggest a clear correlation between a certain colour and a certain emotion (Fehrman and Fehrman 2004; Tofle et al. 2004), and the influence of colour on emotional states as well as on mental and behavioural activities is unjustified due to the lack of validated data in the published literature (Tofle et al. 2004; Young 2007).

Colours do not contain any inherent emotional triggers (Fehrman and Fehrman 2004; Tofle et al. 2004). Our own physiological and psychological makeup at the moment interact with colour and cause changing moods and emotions, which we then think is associated with the colour–emotion response itself (Fehrman and Fehrman 2004). In addition, responses to colour may vary depending on age, gender, culture (culturally learned associations) and personal preference (Tofle et al. 2004; Manav 2007). Any healthcare space does not become ‘active’, ‘relaxing’, or ‘contemplative’ only because of its colour (Tofle et al. 2004).

Artworks

In HCFs, artworks can contribute to wellbeing (Daykin et al. 2008), serve the role of ‘branding’ (improve the perception of care and serve as an element that users identify with) and ‘deinstitutionalization’ (less intimidating) (Hathorn and Upali 2008), as well as have economic outcomes (cost of patient care or cost related to staff turnover, etc.) (Hathorn and Upali 2008).

The beneficial impact of pleasant, preferred art (realistic art depicting serene natural environments) for patients is assumed to be a factor in lowering stress and anxiety levels, improvements in mood (Ulrich 1991, 1999; Ulrich et al. 1993), a reduced depression (Staricoff et al. 2003), a reduced intake of pain medication, lowered blood pressure and heart rate (Ulrich and Gilpin 2003), a shorter post-operative recovery time (Ulrich 1984b; Ulrich et al. 1993; Diette et al. 2003), increasing satisfaction with healthcare services (Ulrich and Gilpin 2003), offering positive distraction (allowing patient and visitors to focus on something other than their own (or other patients’) condition (Hathorn and Upali 2008) and improving wayfinding (pieces of art serve as landmarks) (Hathorn and Upali 2008). Among staff, pleasant art has been associated with reported satisfaction (Ulrich and Gilpin 2003).

Abstract art, and in particular, emotionally challenging or provocative works, are consistently disliked by patients (Ulrich 1991, 1999). Although environmental designers, artists and some healthcare staff react positively to abstract or challenging images, there is mounting evidence that the use of such content or styles in a picture can increase stress and worsen other outcomes in many patients (Ulrich 1991, 1992, 1999). Abstract art may contribute to less favourable recovery outcomes than viewing no pictures at all (Ulrich et al. 1993). There is a need for future studies concerning patient as well as staff perceptions and the influencing factors of artworks (such as the degree of control exercised by patients and staff) in HCFs.

Ergonomic conditions and furniture

Ergonomics is an applied science that aims to optimize performance and productivity and reduce the risks of injury, discomfort and illness (Springer 2007). The goal of ergonomics is to support people in what they do so that they are safe, comfortable and productive. The primary focus is on people as well as on the tools and technology they use (Springer 2007). Healthcare environments
present a unique set of circumstances, opportunities and challenges for applying ergonomics (Springer 2007).

The application of ergonomic principles and the use of ergonomic work tools (i.e. electrical beds and shower trolleys) in HCFs provide a significant opportunity for realizing improved performance, improved worker satisfaction, increased comfort, decreased physical strain and risk of lower back disorders among nursing staff, positive effects on recruitment and retention, and improved quality of patient care in a cost-effective way (Walls 2001; Amick et al. 2002, 2003; Nevala and Tamminen-Peter 2004; Springer 2007). Good ergonomics can also increase a person’s ability to use information and perform tasks. The use of mobile information and communication systems in clinical routines has the potential to greatly improve communication, facilitate access to information, eliminate double documentation, and increase the quality of patient care in the long run, particularly when the appropriate infrastructure is available (Ammenwerth et al. 2000; Toivonen, Choi, and Nevala 2011).

The appropriate furniture design, covering and arrangements in HCFs have been associated with reduced nosocomial infections (CDC and HICPAC 2003; Lankford et al. 2006; Bartley, Olmsted, and Haas 2010; Carling and Bartley 2010; The Facility Guidelines Institute 2010; Malone and Dellinger 2011), decreased medication errors (USP-NF 2010; Westbrook et al. 2010; Malone and Dellinger 2011), decreased patient, family and staff stress and fatigue (Leather et al. 2003; Becker and Douglass 2008; Williams 2008; Malone and Dellinger 2011), improved environmental safety (Aiken et al. 2002; Malone and Dellinger 2011), reduced patient falls and associated injuries (Janssen et al. 2002; Malone and Dellinger 2011), improved communication and social support for patients and family members (Holahan 1972; Melin and Gotestam 1981; Karro, Dent, and Farish 2005; Olsen, Cutcliffe, and O’Brien 2008; Ulrich et al. 2008; Malone and Dellinger 2011) and improved staff effectiveness, efficiency and communication (Malone and Dellinger 2011).

Wayfinding

The navigation of space, based on various environmental cues, is generally called ‘wayfinding’, and is defined as the purposeful, directed and motivated movement from an origin to a specific distant destination that cannot be directly perceived by the traveller (Raubal 2008). ‘Wayfinding’ is a strategy used to assist people in successfully navigating a site and reaching their intended destination. As a strategy or design concept, it takes in the complete site environment, using signage as an essential and major part in the process (NSW Health 2008).

Successful spatial navigation is an important part of a building’s function and gives occupants a feeling of control over their situation. In the often unfamiliar, inherently complex and stressful realm of healthcare environments, wayfinding becomes more critical and complicated (Carpman and Grant 1993) and can cause a loss of control among patients, which can produce stress and negatively affect outcomes (Ulrich 2000; Ulrich et al. 2004). Thus, simple, logical and clearly guided routes in HCFs are an important element of indoor design.

Music

Whereas western medicine has tended to ignore the health benefits of music in the past, recent research, which proves its efficacy for healing and wellbeing, has seen the healing qualities of music become a more important consideration in the design of healing environments. Positive outcomes depend on the ability to listen to music the person likes (Allen and Blascovich 1994), as not all people are likely to prefer the same type of music due to differences in age, culture and peer group (Lee et al. 2005).
Several studies across a variety of patient groups have shown that pleasant music, especially when controllable, can often help patients cope with pain, lower blood pressure, decrease anxiety and distress, decrease depression, decrease heart rate, decrease respiratory rate, bring a higher level of satisfaction with experience, improve memory, decrease behavioural problems and agitation, reduce acute postoperative confusion and delirium, improve coping abilities and speed up recovery (Standley 1986; Menegazzi et al. 1991; Chlan 2000; McCaffrey and Locsin 2004; Chang and Chen 2005; Cooke, Chaboyer, and Hiratos 2005; Goodall and Etters 2005; Lee et al. 2005; Lai et al. 2006; Joseph and Ulrich 2007; Särkämö and Soto 2012).

Only one study was found that examined the impact of music on staff. According to Allen and Blascovich (1994), surgeons reportedly performed better when they listened to music of their own choice. This is an area where future research is needed.

Conclusions
This literature review summarized physical factors of the indoor environment reported to affect human health and wellbeing in HCFs. There is strong evidence to suggest that the acoustic environment, ventilation and air conditioning systems, the thermal environment, the visual environment (e.g. lighting and views of nature), ergonomic conditions and furniture have beneficial effects for all user groups. In contrast, the effect of spatial layouts and room type may have opposing effects among different groups. This review provides a useful, practical resource for all those responsible for the design and operation of the facilities, as well as for healthcare managers, professionals and researchers investigating these factors. Although there is a growing body of literature concerning physical factors and their effects on human beings, the majority of published studies so far have focused mainly on the effects of physical environment factors on patients’ health and wellbeing. Additional studies focusing on all user groups (including healthcare personnel and visitors) and on the interaction among the increasing number of physical elements presented in modern HCF environments are required in order to provide guidance for design and to achieve the optimum indoor environment for all users.

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References


**Supplementary data**

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