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A Review of the Research Literature on Evidence-Based Healthcare Design

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Georgia Tech College of Architecture

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ABSTRACT

This paper was originally published in the spring 2008 issue of HERD (Health Environments Research and Design Journal)*, Vol. 1, No. 3. For more information about* HERD*, visit the Web Site at www.herdjournal.com.*

Objective: This report surveys and evaluates the scientific research on evidence-based healthcare design and extracts its implications for designing better and safer hospitals.

Background: This report builds on a literature review conducted by researchers in 2004.

Methods: Research teams conducted a new and more exhaustive search for rigorous empirical studies that link the design of hospital physical environments with healthcare outcomes. The review followed a two-step process, including an extensive search for existing literature and a screening of each identified study for the relevance and quality of evidence.

Results: This review found a growing body of rigorous studies to guide healthcare design, especially with respect to reducing the frequency of hospital-acquired infections. Results are organized according to three general types of outcomes: patient safety, other patient outcomes, and staff outcomes. The findings further support the importance of improving outcomes for a range of design characteristics or interventions, including single-bed rooms rather than multibed rooms, effective ventilation systems, a good acoustic environment, nature distractions and daylight, appropriate lighting, better ergonomic design, acuity-adaptable rooms, and improved floor layouts and work settings. Directions for future research are also identified.

Conclusions: The state of knowledge of evidence-based healthcare design has grown rapidly in recent years. The evidence indicates that well-designed physical settings play an important role in making hospitals safer and more healing for patients and better places for staff to work.

Key Words: Evidence-based design, hospital design, healthcare design, healthcare quality, outcomes, patient safety, staff safety, infection, hand washing, medical errors, falls, pain, sleep, stress, depression, confidentiality, social support, satisfaction, single rooms, noise, nature, daylight

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INTRODUCTION

Background

A visit to a U.S. hospital is dangerous and stressful for patients, families, and staff. Hospital-acquired infections and medical errors are among the leading causes of death in the United States, each killing more people than automobile accidents, breast cancer, or acquired immune deficiency syndrome (AIDS) (Institute of Medicine [IOM], 2001; Klevens, et al., 2007a). The resulting yearly cost for U.S. hospitals is estimated to be $5 billion for hospital-acquired infections (Centers for Disease Control and Prevention [CDC], 2000) and $17 to $29 billion for medical errors (Kohn, Corrigan, & Donaldson, 1999). According to the IOM (2001) in its landmark *Crossing the Quality Chasm* report: "The frustration levels of both patients and clinicians have probably never been higher. Yet the problems remain. Health care today harms too frequently and routinely fails to deliver its potential benefits" (p. 1). Problems with U.S. healthcare not only negatively influence patients; they affect staff. Registered nurses have a turnover rate averaging 20% (Joint Commission, 2002).

At the same time, a major boom in hospital construction is occurring in the United States and several other countries. The U.S. healthcare system is facing the confluence of the need to replace aging 1970s hospitals, population shifts, the graying of the Baby Boom generation, and the introduction of new medical technologies. As a result, the United States will spend more than $180 billion for new hospitals in the next 5 years alone, and healthcare construction is projected to exceed $70 billion per year by 2011 (Jones, 2007). These new hospitals will remain in place for decades.

This once-in-a-lifetime construction program provides an opportunity to rethink hospital design and especially to consider how better design can improve patient and staff outcomes. Just as medicine has increasingly moved toward *evidence-based medicine* where clinical choices are informed by research, healthcare design is increasingly guided by rigorous research linking hospitals' physical environments to healthcare outcomes, and it is moving toward *evidence-based design* (EBD) (Hamilton, 2003). For example, The Center for Health Design Pebble Project includes approximately 50 healthcare providers and manufacturers committed to using EBD for their construction projects. The Military Health System has adopted EBD for a $6 billion capital construction program for its 70 hospitals, which serve more than 9.2 million people worldwide. Kaiser Permanente and its partners in the Global Health and Safety Initiative are using EBD as a strategy to increase *triple safety* for patients, staff, and the environment. The Global Health and Safety Initiative comprises partners that provide over 100,000 hospital beds.

This report is an updated and expanded version of a 2004 report, "The Role of the Physical Environment in the Hospital of the 21st Century" (Ulrich, Zimring, Quan, Joseph, & Choudhary, 2004). Research teams from Texas A&M University and the Georgia Institute of Technology conducted a new and more extensive search for empirical studies linking the design of the physical environments of hospitals with healthcare outcomes. The following questions are explored in this study: (1) What can rigorous research tell us about "good" and "bad" hospital design? (2) Can improved design make hospitals less risky and stressful and promote more healing for patients, their families, and staff? (3) Is there scientifically credible evidence that design affects clinical outcomes and staff effectiveness in delivering care?

Methodology

This review followed a two-step process. First, we conducted key word searches to identify potentially relevant studies published in English. Thirty-two key words were used, referring to patient and staff outcomes (such as *infection, medical error, pain, sleep, depression, stress,* and *privacy*), physical environmental factors *(hospital, hospital units, healthcare facility*, etc.), and other healthcare-related issues (such as *patient-*

and *family-centered* care). We conducted an extensive series of cross-searches using combinations of key words through the EBSCO research database, which enabled the simultaneous search of multiple databases, such as Academic Search Premier, Alt Healthwatch, MED-LINE, PsycArticles, Psychology and Behavioral Sciences Collection, PsycINFO, and CINAHL. In addition, a supplemental search was conducted through the ISI Web of Knowledge and Google Scholar. The search included any study that alluded or referred to the physical environment of healthcare buildings in the title or the abstract. We also obtained additional relevant studies from the reference lists of identified articles.

In the second stage, we screened all identified references using two criteria: First, the study should be empirically based and examine the influence of environmental characteristics on patient, family, or staff outcomes. Second, the quality of each study was evaluated in terms of its research design and methods and whether the journal was peer-reviewed.

Summary of Key Findings

We found a growing number of rigorous studies that help establish the relationship between the physical design of hospitals and key outcomes. This report was organized according to three general types of outcomes. The first section focuses on *patient safety issues,* such as infections, medical errors, and falls. The second section examines studies related to *other patient outcomes,* such as pain, sleep, stress, depression, length of stay, spatial orientation, privacy, communication, social support, and overall patient satisfaction. The third section surveys the scientific research relevant to *staff outcomes,* such as injuries, stress, work effectiveness, and satisfaction. Although these outcomes were also discussed in the 2004 report, this new study has substantially expanded the scale of most sections. In particular, the section on hospital-acquired infections has been substantially revised and expanded, reflecting the rising severity and importance of infections, the rapid growth of infection research, and the appearance of several new studies directly relevant to hospital design. The last section of the paper, Conclusions and Design Recommendations, summarizes the findings according to design characteristics or interventions and their implications for various outcomes.

Overall, this review confirms the importance of improving the healthcare outcomes associated with a range of design characteristics or interventions, such as single-bed rooms rather than multibed rooms, effective ventilation systems, a good acoustic environment, appropriate lighting, better ergonomic design, and improved floor layouts and work settings. Compared to 2004, the body of evidence has grown rapidly and substantially in recent years. This is encouraging given that the importance of EBD has increased markedly as the need for better healthcare facilities has grown and become more urgent. It is now widely recognized that well-designed physical settings play an important role in making hospitals less risky and stressful, promoting more healing for patients, and providing better places for staff to work.

However, it is also important to address the limitations of the quality of existing evidence. In medical fields, a *randomized controlled trial* or *experiment* is considered the strongest research design for generating sound and credible empirical evidence. Our literature review, however, found relatively few randomized controlled trials linking specific design features or interventions directly to impacts on healthcare outcomes. This is not very surprising, because most changes of the physical environment in healthcare settings alter several environmental factors simultaneously. This creates confounding variables and makes it difficult to disentangle the independent effect of the environmental change of primary interest. As an example, renovating an intensive care unit (ICU) with two-bed patient rooms to create single-bed rooms would likely alter not only the number of patients per room, but also the ratio of hand-washing sinks per bed and possibly the room ventilation or air quality. However, there are certain design interventions that may alter only one environmental factor, and the intervention can be assigned randomly to some patients but not others. Examples include exposing patients to interventions such as nature distraction, art, and reduced noise. In the case of these types of interventions, particularly nature distraction, our literature search identified a number of prospective randomized clinical trials that provide strong evidence. Additionally, we identified many moderately strong quasi-experimental studies, and some well-conducted epidemiological investigations. The largest category of studies consisted of observational studies with or without control groups.

Although many studies are not well controlled, the strength of evidence is enhanced by the fact that in the case of certain environmental factors, *reliable patterns of findings* across several studies emerged with respect to outcome influences. Furthermore, these patterns were broadly consistent with predictions based on established knowledge and theory concerning environment and healthcare outcomes. For example, many studies have consistently found that high noise levels in hospitals worsen patient outcomes such as sleep quality, physiological stress, and satisfaction. It is important to note that validity is strengthened when findings tend to be reliable or consistent and are in accord with a priori hypotheses or predictions derived from previous knowledge. Thus, we believe the application of such findings in EBD should be encouraged despite the shortage of randomized experimental trials. On the other hand, future research should be carefully designed and controlled so that the independent role of specific environmental changes or interventions can be better understood.

Different Ways of Reading This Report

This report is written for readers from different disciplines and professions, including architects, healthcare professionals, administrators, and researchers in EBD or healthcare-related fields. It covers a wide range of topics and surveys hundreds of studies and therefore makes an exceptionally long article. It is organized in a systematic way to accommodate the needs of different readers and to facilitate reading at different levels of detail and scope, including: (1) reading the entire article; (2) reading through the article more quickly by looking at the Summary of Evidence and Recommendations that appears at the beginning of each section; (3) reviewing the subtitles and thoroughly reading one or more individual sections on specific outcomes of interest; and (4) reading the last section of the paper, Conclusions and Design Recommendations, to extract major findings and recommendations organized according to specific design issues.

In addition, readers may notice instances of redundancy, where the same study has been cited in different sections. This is necessary because some characteristics of hospital physical environments (such as nature destruction and noise) influence multiple outcomes. Therefore, certain studies are cited in multiple sections, each focusing on a different outcome. Second, as mentioned previously, some readers may choose to read individual sections related to their specific interests. Cross-references would make reading difficult for such readers. To avoid this, some studies have been cited in more than one place in the article.

RESULT I: IMPROVING PATIENT SAFETY THROUGH ENVIRONMENTAL MEASURES

Reducing Hospital-Acquired Infections

Summary of Evidence and Recommendations

One critically important way that EBD improves safety is by reducing the risk of hospital-acquired infections (i.e., nosocomial infections), a leading cause of death in the United States. One general conclusion supported by the infection literature is that the design of the physical environment impacts nosocomial infection rates by affecting all three major transmission routes—air, contact, and water. This discussion addresses the three transmission routes separately and is followed by a discussion of several advantages of single-bed rooms, as compared to multibed rooms, in controlling infection.

There is a pattern across scores of studies indicating that infection rates are lower when there is very good air and water quality, and greater physical separation, isolation, or space per patient. Concerning hand washing, there is evidence that providing accessible, alcohol-based hand-rub dispensers at the bedside can increase hand-washing compliance and thereby reduce contamination spread by contact.

The large amount of research literature reviewed in this section strongly supports the following design measures for controlling and preventing infection:

- Use effective air quality control measures during construction and renovation to prevent the outbreak of airborne infections. Measures include, for example, using portable high-efficiency particulate air (HEPA) filters, installing barriers between patient-care areas and construction/renovation areas, generating negative air pressure for construction/renovation areas relative to patient-care areas, and sealing patient windows.
- Install alcohol-based hand-rub dispensers at the bedside and in other accessible locations to increase hand-washing compliance and reduce contact transmission of infection.
- Select easy-to-clean floor, wall, and furniture coverings, and employ proper cleaning and disinfection procedures.
- Design and maintain the water system at the proper temperature and adequate pressure; minimize stagnation and back flow; eliminate dead-end pipes; regularly clean point-of-use fixtures; and consider the location of decorative fountains and carefully maintain them to minimize the risk of waterborne infection.
- Provide single-bed rooms with private toilets to enable separation or isolation of patients on admission, so that those with unrecognized infections can be tested and identified without being mixed in with uninflected individuals in multibed rooms; to reduce airborne infection transmission by increasing isolation capacity and facilitating the maintenance of good air quality through measures such as effective ventilation, filtration, and appropriate air flow direction and pressure (positive or negative); and to facilitate thorough cleaning after a patient leaves, including the use of decontamination methods such as hydrogen peroxide vapor (HPV), which may be much more effective than conventional cleaning.

Hospital-Acquired Infections: A Serious and Growing Problem

Hospital-acquired infection is one of the leading causes of death in the United States. In 2002 alone, hospital-acquired infections in U.S. hospitals numbered approximately 1.7 million, and the number of associated deaths reached 98,987 (Klevens et al., 2007a). This means that approximately 1 of every 22 hospitalized patients acquired an infection. According to the CDC (2000), the cost of treating hospital-acquired infections is estimated to be $5 billion per year. Many hospital-acquired infections are drug resistant and difficult to treat and eradicate. Patients are especially vulnerable to these infections when they are immunocompromised or otherwise weakened by age, medical or surgical treatments, or underlying disease (Weinstein, 1998). The international trend toward increasing intensity of care and patient acuity (American Hospital Association, 2005) portends a future of greater patient vulnerability to infection.

The importance of controlling hospital-acquired infection is increasingly recognized by health authorities and the general public as a crucial dimension of healthcare quality. The CDC and Healthcare Infection Control Practices Advisory Committee (HICPAC) have issued guidelines for infection control in healthcare facilities (Sehulster et al., 2004). A telephone survey of a national sample of U.S. households found that 93% of respondents indicated that if information on hospital infection rates were provided, it would influence their selection of hospitals (McGuckin, Waterman, & Shubin, 2006).

This research team identified a very large amount of scientific research pertinent to understanding the influences of the hospital physical environment on infection transmission and control. Generally speaking, infection transmission occurs via three routes: *contact, air,* and *water*. Contact is widely considered the principal or most frequent transmission route. In reality, these three routes may intertwine with each other in the spread of nosocomial infections. Advances in molecular detection methods and sampling techniques for viruses, bacteria, and fungi have enabled researchers to identify the exact strain and source of infections, and thereby develop a better understanding of transmission.

Reducing Infections Caused by Airborne Pathogens

Airborne transmission refers to infections that are contracted from airborne micro-organisms. Reservoirs for airborne pathogens range from dust (e.g., spores of *Clostridium Difficile* or *C. Diff.* and *Aspergillus*) to aerosol droplets (e.g., tuberculosis [TB], severe acute respiratory syndrome [SARS], influenza, chickenpox), to skin scales shed by patients infected with methicillin-resistant *Staphylococcus aureus* (MRSA) (Ulrich & Wilson, 2006). Airborne transmission has also been implicated in outbreaks of other infections such as *Acinetobacter spp*. and *Pseudomonas spp*. (Beggs, 2003; Beggs, Kerr, Snelling, & Sleigh, 2006). The relative importance of airborne transmission remains somewhat controversial (Bauer, Ofner, Just, Just, & Daschner, 1990). Brachmans's early study (1970) estimated that airborne transmission accounted for 10–20% of nosocomial infections. Beggs (2003) argued that the role of airborne transmission may have been underestimated, due to the difficulty of culturing many airborne organisms and the complexities of assessing the role such pathogens play in the contamination of environmental surfaces and subsequent contact transmission. Recently airborne infections have attracted more attention due to outbreaks of SARS in 2002–2003 and current concerns about an avian influenza (H5N1) pandemic. A few extensive research reviews have been conducted, notably Li et al.'s review (2007) on the relationship between ventilation systems and airborne transmission; Tang, Li, Eames, Chan, and Ridgway's report (2006) on airborne infection and ventilation control in healthcare settings; and Beggs' review (2003) on the importance of airborne transmission in healthcare-acquired infections.

This literature survey identified many studies that explicitly examine the relationships between airborne infections and environmental factors in healthcare buildings. There is a pattern of findings across these studies suggesting that hospital air quality plays a decisive role in affecting the concentration of pathogens in the air, and thereby has major effects on the frequency of airborne infectious diseases such as TB, aspergillosis, chickenpox, influenza, and SARS. The research also clearly indicates that multiple environmental approaches or interventions can be effective in controlling and preventing airborne infections. Though a sizable amount of sound research is available, data on certain aspects of air quality and infection are insufficient to permit the precise specification of, for example, minimum ventilation and filtration requirements for certain patient groups and treatment spaces (Li et al., 2007), or the maximum tolerable level of spores per cubic meter (Bouza et al., 2002) for the prevention of airborne transmission.

Sources and Environmental Routes of Airborne Infections

Airborne pathogens originate from different sources. Most pathogens in healthcare settings originate from patients, staff, and visitors within the buildings, from such sources as infected patients' respiratory tracts or skin squamae (scales). Other pathogens can enter buildings from *outside air* through dust that harbors pathogens such as *aspergillus, streptococci, or staphylo-*

occi (Beggs, 2003). There are also less common sources of airborne infections; for example, bird droppings or aerosols from contaminated water in a warm-water therapy pool (Angenent, Kelley, St Amand, Pace, & Hernandez, 2005).

Several environmental factors and conditions have been identified as frequent sources of airborne infection outbreaks. The malfunction or contamination of ventilation systems and lack of cleaning and maintenance are commonly cited (Kumari et al., 1998; Lutz, Jin, Rinaldi, Wickes, & Huycke, 2003; McDonald et al., 1998; Schultz et al., 2003). In one MRSA outbreak, for example, the ventilation grilles in two patient bays were found to be harboring MRSA (Kumari et al., 1998). On occasions when this ventilation system was shut down, it sucked air from the ward environment into the system, contaminating the outlet grilles then it blew contaminated air back into the ward when the system was restarted. Additionally, several studies have identified hospital construction and renovation activities as the sources of airborne infection outbreaks due to dust or particulate generation (Humphreys et al., 1991; Iwen, Davis, Reed, Winfield, & Hinrichs, 1994; Loo et al., 1996; Opal et al., 1986; Oren, Haddad, Finkelstein, & Rowe, 2001).

Environmental Approaches for Reducing Airborne Infections

The research literature strongly supports implementing several environmental approaches for controlling and preventing airborne infections, including installing effective filters, specifying appropriate ventilation systems and air change rates, employing various control measures during construction or renovation, and using single-bed rooms instead of multibed rooms to increase isolation capacity and reduce transmission from infected patients. Also, limited research suggests that measures such as the use of ultraviolet irradiation can be effective in reducing airborne pathogens (Griffiths, Bennett, Speight, & Parks, 2005) and lowering the incidence of asthma in asthmatic children's homes (Bernstein et al., 2006).

High-efficiency particulate air (HEPA) filters. An effective way to control infections is to control their source. Filtration, the physical removal of particulates from air, is often the first step in ensuring good air quality. One experimental study of a commercial air purification system found that a chemical-coated filter demonstrated 61.46% efficiency in destroying pathogens and reached 99.99% efficiency when used in conjunction with ultraviolet lamps (Griffiths et al., 2005). In acute healthcare settings, a commonly used approach is the HEPA filter, which can be at least 99.97% efficient for removing particulates as small as 0.3 μm in diameter (as a reference, *Aspergillus* spores are 2.5 μm to 3.0 μm in diameter) (Sehulster et al., 2004). This is adequate for most healthcare settings in ambulatory care facilities and hospitals, including operating rooms (ORs) (Sehulster et al., 2004). Boswell and Fox's study (2006) revealed a significant reduction in environmental contamination by MRSA with the use of portable HEPA units in a clinical setting. In the CDC/HICPAC guidelines, the use of HEPA filtration is recommended for healthcare facilities, and it is either required or strongly recommended for all construction and renovation areas (Sehulster et al., 2004).

There is strong evidence that immunocompromised and other high-acuity patients have a lower incidence of infection when housed in HEPA-filtered isolation rooms. Bone-marrow transplant recipients in one study showed a 10-fold greater incidence of nosocomial *Aspergillus* infection when they were assigned beds outside a HEPA-filtered environment with *laminar airflow* (LAF), as compared to similar patients housed in a HEPA-filtered unit (Sherertz et al., 1987). A strong multisite study by Passweg and colleagues (1998) found that the use of HEPA and/or LAF reduced infections, decreased transplant-related mortality, and increased survival for leukemia patients after bone marrow transplant.

Ventilation systems and airflow control. After air is filtered, effective ventilation systems are needed to achieve optimal ventilation rates, airflow patterns, and humidity so that the spread of infections can be minimized. First, *ventilation rate* is an important measure to control indoor air quality. In healthcare facilities, it is usually expressed as room air changes per hour (ACH), where peak efficiency for particle removal in the air space often occurs between 12 ACH and 15 ACH. In a study of SARS infections, wards with the highest ventilation rate had a significantly lower infection rate among healthcare workers as compared with other wards (Jiang et al., 2003). A study of 17 Canadian hospitals found that the risk of healthcare workers acquiring TB was strongly linked with exposure to infected patients in rooms with low ACH rates, such as waiting areas (Menzies et al., 2000). Detailed ventilation standards are provided by the American Institute of Architects (AIA) and Facilities Guidelines Institute (FGI) in the *Guidelines for Design and Construction of Health Care Facilities* (AIA & FGI, 2006), and by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) in *ASHRAE 62.1-2004—Ventilation for Acceptable Indoor Quality* (ASHRAE, 2004). Yet questions remain regarding the minimum ventilation requirements needed for effective prevention of infections (Li et al., 2007).

A second key aspect of ventilation is *airflow direction*. Negative pressure is preferred for rooms housing infectious patients to prevent the dispersion of pathogen-laden aerosols, dust, and skin scales from the locus of the infected patient to other spaces. Importantly, a review of 40 studies by Li et al. (2007) concluded that there is strong evidence to support and recommend the use of negatively pressurized isolation rooms. By contrast, if a care space houses an immunocompromised patient (e.g., surgical patients, patients with underlying chronic lung disease, or dialysis patients) or immunosuppressed patients (e.g., transplant patients or cancer patients), positive airflow pressure is desirable to safeguard them from aerial pathogens entering from adjacent spaces.

Finally, an exceptionally effective ventilation approach for maintaining indoor air quality is to use LAF, which is HEPA-filtered air blown into a room at a rate of 90 ± 10 feet/min in a unidirectional pattern with 100–400 ACH (Sehulster et al., 2004). When combined with HEPA filters, LAF can reduce air contamination to the lowest level; thus it is recommended for ORs and areas with ultraclean room requirements, such as those housing immunocompromised patients (Alberti et al., 2001; Arlet, Gluckman, Gerber, Perol, & Hirsch, 1989; Dharan & Pittet, 2002; Friberg, Ardnor, Lundholm, & Friberg, 2003; Hahn et al., 2002; Sherertz et al., 1987). A prospective cohort study found that the type of operating theater ventilation was an independent risk factor for the incidence of sternal surgical site infections (Yavuz et al., 2006). New theaters with LAF and automatically closing doors showed significantly better results in reducing infections than older theaters with conventional plenum ventilation.

Effective air quality control measures during construction and renovation. It is extremely important to employ effective control and prevention measures during construction and renovation, because such activities have been frequently implicated in outbreaks of airborne infection. Examples of such measures include using portable HEPA filters, installing barriers between patient-care areas and construction/renovation areas, generating negative air pressure for construction/renovation areas relative to patient-care areas, and sealing patient windows. Strong evidence indicates that using HEPA filters for air intakes near construction and renovation sites has positive effects on air quality and reduces the risk of infection for patients (Bouza et al., 2002; Cornet et al., 1999; Loo et al., 1996; Mahieu, De Dooy, Van Laer, Jansens, & Ieven, 2000; Opal et al., 1986; Oren et al., 2001). For example, a study conducted during extensive hospital construction and renovation documented an outbreak of invasive pulmonary aspergillosis (IPA) among acute leukemia patients housed in wards with natural ventilation, soaring to an infection rate of 50% (Oren et al., 2001). At this point some patients were moved to a hematology ward with HEPA filters. During the following 3 years, none of the patients hospitalized in the hematology ward developed IPA, although 29% of leukemia patients housed in the regular ward contracted aspergillosis. However, one strong study demonstrated that HEPA filters were not by themselves an adequate control measure during construction; they should be employed in conjunction with other measures such as sealing windows and installing barriers (Humphreys et al., 1991). It was noted earlier that the combination of LAF and HEPA filtration is capable of reducing air contamination to the lowest level. During construction or renovation activities, however, LAF is more expensive and especially difficult to achieve, because furnishings and other features can create turbulence. There is currently a lack of cost-benefit research to enable well-founded evaluations of the expense versus effectiveness of LAF for patient-care areas near construction and renovation sites.

Reducing Infections Spread by Contact

Although airborne transmission poses serious safety risks, contact contamination is generally recognized as the principal transmission route of nosocomial infections, including pathogens such as MRSA, *C. difficile,* and vancomycin-resistant enterococci (VRE), which survive well on environmental surfaces and other reservoirs (Bauer et al., 1990; IOM, 2004). The prevention of contact-spread infections is of paramount importance in healthcare settings.

Sources and Environmental Routes of Contact-Spread Infections

Environmental routes of contact-spread infections include direct person-to-person contact and indirect transmission via environmental surfaces. *Healthcare workers' hands* play a key role in both direct and indirect transmissions. A staff member may touch two patients in succession without washing his or her hands, or touch an environmental surface or feature after direct contact with an infected patient. Other staff and the patient may then acquire the pathogen by touching the same surface (Ulrich & Wilson, 2006). Research indicates that there is an inverse causal link between the hand-washing compliance rate of healthcare workers and contact transmission of infectious diseases (Larson, 1988, 1999). It is well established that hand hygiene is the most important single measure for preventing the spread of pathogens in healthcare settings (Boyce & Pittet, 2002).

In this context, the fact that hand-washing compliance rates are often low represents a very serious challenge to patient safety. Mallaret et al. (1998) reviewed 38 studies and reported that compliance rates were usually less than 40%. In more recent studies, compliance rates were still low, with most ranging between 20% and 35%; rates above 40% or 50% are the exception (Albert & Condie, 1981; Graham, 1990; Kuzu, Ozer, Aydemir, Yalcin, & Zencir, 2005; Larson, Albrecht, & O'Keefe, 2005; Randle, Clarke, & Storr, 2006; Saba et al., 2005; Sacar et al., 2006; Trick et al., 2007). Compliance rates usually are lower for indirect contact (through environmental surfaces) than for direct person-to-person contact (McArdle, Lee, Gibb, & Walsh, 2006). There is a pattern that compliance is worse in high-acuity units such as ICUs, because patient care in these units is often more demanding than in lower-acuity units (Karabay et al., 2005). Meanwhile, guidelines require staff to clean their hands more frequently when caring for sicker patients (Karabay et al., 2005). Hand hygiene tends to be especially poor in units that are busy due to understaffing and/or a high bed-occupancy rate or patient census (Archibald, Manning, Bell, Banerjee, & Jarvis, 1997). High bed-occupancy rates have been identified as a factor contributing to higher rates of infections such as MRSA (Borg, 2003).

Furthermore, *environmental surfaces* in healthcare settings often become extensively contaminated by nearby patients or by healthcare workers' contaminated hands. Boyce, Potter-Bynoe, Chenevert, and King (1997) found that in rooms housing patients infected with MRSA, 27% of all environmental surfaces sampled were contaminated. Meanwhile, 42% of nurses who had no direct contact with MRSA patients but who had touched environmental surfaces contaminated their gloves with MRSA. Other research reports even higher levels of MRSA surface contamination (74%) in spaces previously occupied by colonized or infected patients (French et al., 2004). The same study found MRSA contamination in 100% of patient rooms sampled, regardless of whether or not the previous occupant had been infected. Furthermore, patient rooms can become contaminated with more than one type of MRSA, suggesting prolonged survival of MRSA strains from prior room occupants (French et al., 2004). It is not surprising that the risk of acquiring antibiotic-resistant infections such as MRSA and VRE is significantly increased if a patient is admitted to a room previously occupied by an infected individual (Huang, Datta, & Platt, 2006).

Because many nosocomial pathogens can survive on environmental surfaces for weeks or months (Bonilla, Zervos, & Kaufman, 1996; Kramer, Schwebke, & Kampf, 2006), such contaminated surfaces act as pathogen reservoirs and can become the source of infection outbreaks (Boyce et al., 1993; Lankford et al., 2006). Many of these environmental surfaces and features have direct relevance to architectural design, including floors (Anderson, Mackel, Stoler, & Mallison, 1982; Beyer & Belsito, 2000; Boyce et al., 1997; Skoutelis, Westenfelder, Beckerdite, & Phair, 1994), work surfaces or furniture such as chairs (Noskin, Bednarz, Suriano, Reiner, & Peterson, 2000), bed privacy curtains (Palmer, 1999), door handles (Roberts, Findlay, & Lang, 2001), sink faucets (Blanc et al., 2004; Bures, Fishbain, Uyehara, Parker, & Berg, 2000), bedside rails, over-bed tables, bed linens and patients' gowns (Boyce et al., 1997), clinical waste carts (Blenkharn, 2006), computer keyboards (Bures et al., 2000), bedside patient files (Panhotra, Saxena, & Al-Mulhim, 2005), and even toys in healthcare settings (Fleming & Randle, 2006; Merriman, Corwin, & Ikram, 2002). Other very frequently contaminated surfaces and objects include medical equipment such as infusion pumps (Aygun et al., 2002), blood pressure cuffs (Boyce et al., 1997), laryngoscope blades (Beamer & Cox, 1999), stethoscopes (Marinella, Pierson, & Chenoweth, 1997), and electronic ear-probe thermometers (Porwancher et al., 2001). The pervasiveness of such contamination underscores the importance of hand and workplace hygiene in healthcare settings (Wilson & Ridgway, 2006; Ulrich & Wilson, 2006).

Environmental Approaches to Reduce Contact-Spread Infections

The research literature supports the effectiveness of certain environmental approaches for controlling and preventing contact-spread infections. Examples of such approaches include providing sufficient and accessible alcohol-based hand-rub dispensers, choosing easy-to-clean furniture and wall finishes, and providing single rooms rather than multibed rooms.

Reducing contact transmissions by increasing hand-washing compliance. Education programs to increase hand-washing compliance alone have yielded, at best, mixed results (Bischoff, Reynolds, Sessler, Edmond, & Wenzel, 2000). Some investigations have found that education interventions generate no increase in hand washing. Even intensive education or training programs, such as classes and group feedback, may produce only transient increases in hand washing (Dorsey, Cydulka, & Emerman, 1996; Dubbert, Dolce, Richter, Miller, & Chapman, 1990). Recently, multifaceted interventions, in addition to education, have been more successful at increasing hand washing. These interventions include environmental measures such as providing localized availability of alcohol-rub dispensers and using posters as reminders to staff (Creedon, 2005; Gordin, Schultz, Huber, & Gill, 2005; Johnson et al., 2005; Lam, Lee, & Lau, 2004; Pittet et al., 2000; Randle et al., 2006; Trick et al., 2007).

There is mounting evidence that the *type* of hand-washing facility influences hand-washing compliance and infection rates. Compared with traditional soap and water, alcohol-based hand-rub acts more rapidly and effectively, requires less time for staff to decontaminate their hands adequately, and has a lower risk of side-effects and recontamination (Boyce & Pittet, 2002). The CDC/HICPAC guidelines define alcohol-based hand-rub as the standard of care for hand hygiene practices in healthcare settings (Boyce & Pittet, 2002). Several studies have shown that the introduction of alcohol-based hand-rub boosted hand-washing compliance (Hugonnet, Perneger, & Pittet, 2002; Johnson et al., 2005; Trick et al., 2007). Importantly, several other studies supported the effectiveness of alcohol-based hand-rub, compared to soap and water, for improving the effectiveness of hand washing in terms of reducing microbial counts on hands (Bischoff et al., 2000; Cohen, Saiman, Cimiotti, & Larson, 2003; Girou, Loyeau, Legrand, Oppein, & Brun-Buisson, 2002; Graham, 1990; Karabay et al., 2005; Tvedt & Bukholm, 2005) and reducing infection rates (Gordin et al., 2005). MacKenzie and colleagues (2007) analyzed MRSA prevalence in more than 100 hospitals across Europe and found that the use of alcohol-based hand-rub was the single most important predictor of lower MRSA incidence after adjusting for other confounding factors. These findings have implications for designers, because alcohol-based hand-rub dispensers are small and inexpensive, and they do not require costly plumbing systems and sinks. These characteristics afford more flexibility than soap-and-water facilities, which in turn facilitates the distribution of dispensers to more locations, closer to patient-care activities and work spaces, thereby making them more accessible to busy clinicians and other staff.

The *number* and *accessibility* of hand-washing facilities also influence compliance and infection rates. In particular, the evidence suggests that installing alcohol-based hand-rub dispensers at the bedside usually improves adherence. Four studies examined the impact of multifaceted interventions that prominently included the provision of bedside alcohol-based hand-rub dispensers, and all demonstrated significant improvements in hand-washing compliance (Bischoff et al., 2000; Creedon, 2005; Pittet et al., 2000; Randle et al., 2006). Another study made a statistical adjustment for other known risk factors of poor hand-washing adherence; the positive effects of the intervention remained significant and were accompanied by decreased infection rates (Pettit et al., 2000). In an observation study, researchers compared the 3 years after the installation of alcohol-based hand-rubs in all rooms with the 3 prior years with fewer soap-and-water sinks; they observed a 21% decrease in MRSA infections and a 41% decrease in VRE infections. Although hand-washing compliance was not measured in this study, it is likely that it may have played a role in this improvement. In contrast to the effectiveness of locating hand-rub dispensers at the bedside, Muto, Sistrom, and Farr (2000) found that installing dispensers in hallway locations (near the doors to patient rooms) did not significantly increase the frequency of hand washing. Other investigations focusing on traditional sinks (soap-and-water) have obtained mixed results concerning the impact of increasing the number and accessibility of sinks, with a few studies reporting positive impacts (Kaplan & McGuckin, 1986); one finding a transient increase in compliance (Whitby & McLaws, 2004); and other studies reporting no significant changes (Lankford et al., 2000, 2003; Vernon, Trick, Welbel, Peterson, & Weinstein, 2003).

Automated technology has also been examined for its impact on hand-washing compliance for soap-and-water sinks and alcohol-based hand-rub dispensers. For traditional soap-and-water hand washing, automated sinks or faucets have shown mixed results (Larson et al., 1991; Larson, Bryan, Adler, & Blane, 1997). Simplicity of use seems to be important to the success of automation. In this regard, limited research suggests that automated touch-free alcohol-based rub dispensers are easy to use and are used more frequently than manual dispensers (Larson, Albrecht, & O'Keefe, 2005). Swoboda, Earsing, Strauss, Lane, and Lipsett (2004) examined the effect on compliance of an automatic system that monitored entries and exits from patient rooms, recorded usage of sinks and alcohol-based hand-rub dispensers, and incorporated voice-prompt devices that reminded healthcare workers and visitors to wash their hands. The system improved hand-cleaning compliance from 19% to 27% and was associated with a reduction in the nosocomial infection rate.

There are some limitations, however, in current hand-washing research knowledge. Because many studies have employed multifaceted interventions, it is not clear how much of the effectiveness of increased hand washing, reduced microbial counts, or reduced infection rates can be attributed to the installation of more numerous and/or accessible alcohol-based hand-rub dispensers. Future research should include prospective controlled experiments, for example, that systematically vary the number and location of alcohol hand-rub dispensers. There is also a conspicuous need for studies that define accessible locations for hand-washing facilities in an evidence-based manner—that is, on the basis of empirical analysis of staff movement paths, visual fields, interactions with patients and families, and work processes. In this regard, the neglect of human factors and research methods are major weaknesses of hand-washing research and of the infection control literature in general. Research teams should include a human factors specialist and sometimes an environmental psychologist. The urgent need to increase hand-washing frequency underscores the high priority that should be accorded to this research direction.

Reducing contact transmission by controlling surface contamination. As previously mentioned, contaminated environmental surfaces often serve as an intermediate step in the contact spread of infections. Several design-related factors should be considered to minimize the risk of infection stemming from contaminated surfaces.

Selection of *appropriate floor and furniture coverings* is an important step, where ease of cleaning should be a key consideration. Some studies have examined flooring materials (Anderson et al., 1982; Skoutelis et al., 1994) and furniture coverings (Lankford et al., 2006; Noskin et al., 2000) as they relate to environmental contamination in healthcare settings. The use of *carpet* can be a controversial issue. On one hand, many people believe that carpet is more difficult to clean than hard floor coverings (Harris, 2000). A few studies have identified carpeting as susceptible to contamination by fungi and bacteria (Anderson et al., 1982; Beyer & Belsito, 2000; Boyce et al., 1997; Skoutelis et al., 1994). However, a recent rigorous study suggests that certain serious pathogens such as VRE survive less well or for shorter periods on carpet than on other floor coverings, including rubber tile, linoleum, vinyl sheet goods, and vinyl composition tile (Lankford et al., 2006). In addition to discovering that carpet harbors less VRE, this research found that carpeting transferred less VRE to hands via contact than rubber and vinyl flooring and performed as well in cleaning as any other floor covering tested (Lankford et al., 2006). There is limited research comparing the air above carpeted areas and hard flooring with respect to concentrations of micro-organisms, and the findings are conflicting. Anderson et al. (1982) found higher concentrations above carpeted areas, whereas Harris (2000) reported higher particulate concentrations above hard flooring.

In summary, the advantages and disadvantages of carpeting versus other floor coverings with respect to infection control are neither clear-cut nor fully resolved. However, in judging different floor coverings, it should be kept in mind that carpeting, compared to hard floorings, offers important advantages unrelated to infection control, including noise reduction (Philbin & Gray, 2002), greater ease of walking and perceived safety for the elderly (Wilmott, 1986), a possible reduction in falls (Counsell et al., 2000), longer family visits in patient rooms, and more positive evaluations and emotional responses from patients and families (Harris, 2000).

It is worth mentioning that CDC/HICPAC guidelines do not recommend against the use of carpeting in patient-care areas. However, the guidelines suggest that carpeting should be avoided in areas where spills are likely to occur or where patients are at greater risk of airborne infections (Sehulster et al., 2004). Similarly, the EBD standards for neonatal intensive care units (NICUs) of the National Perinatal Association state that suitable flooring materials "include resilient sheet flooring (medical grade rubber or linoleum) and carpeting with an impermeable backing, heat- or chemically welded seams and antimicrobial and antistatic properties. Carpeting has been shown to be an acceptable floor covering in the hospital and the NICU and has obvious aesthetic and noise reduction (NR) appeal, but it is not suitable in all areas (e.g., around sinks or in isolation or soiled utility/holding areas)" (White, 2006, p. S12).

The selection of *furniture-covering materials* may also influence the incidence of contamination and risk of infection. Noskin et al. (2000) identified fabric-covered furniture as a source of VRE infection in hospitals and suggested the use of easily cleanable, nonporous material. Another study compared the performance of a variety of furniture upholstery types with respect to VRE and *Pseudomonas aeruginosa* (PSAE) contamination (Lankford et al., 2006). Performance was similar across different furniture coverings in terms of reductions in VRE and PSAE after cleaning and the transfer of VRE and PSAE to hands through contact. However, for the ability to harbor pathogens, although upholstery types showed no differences with respect to PSAE, there was a difference related to VRE. Vinyl upholstery performed the best for VRE—that is, the VRE pathogen survived less well or for shorter periods on vinyl (Lankford et al., 2006). In addition, as with evaluating carpeting and other floor coverings, it is worth considering that fabric-covered furniture might foster a more home-like, less institutional feeling. The CDC/HICPAC guidelines for upholstery are broadly similar to those for carpeting in that they do not recommend against using it in patient-care areas, but they suggest minimizing its use in areas housing immunocompromised patients (Sehulster et al., 2004).

A limited amount of research has compared different *wall finishes* and *metals* with respect to their infection control properties. One study evaluated the effectiveness of copper, brass, and stainless steel surfaces in reducing the viability of air-dried deposits of MRSA (Noyce, Michels, & Keevil, 2006). The results suggested that copper had a better antimicrobial effect than stainless steel. The use of antimicrobial metals such as copper may not reduce the need for careful cleaning, however, because dirt or dust on their surfaces may diminish or eliminate their antimicrobial effects. Lankford and colleagues (2006) compared the performance of different wall finishes (latex paint with eggshell finish, microperforated vinyl, vinyl with nonwoven backing, and Xorel® wall covering), and reported that all harbored VRE and were capable of transferring the pathogen through hand contact. No reduction in VRE was found 7 days after inoculation for two of the wall products—Type II microvented vinyl with paper backing and Xorel® wall covering—indicating that harboring was a greater problem than for other wall products tested. Latex paint with eggshell finish performed worse in cleaning and disinfection than other wall finishes, indicating that cleaning produced inadequate reduction of VRE and PSAE (Lankford et al., 2006).

Proper cleaning and disinfection is another very important step in preventing the spread of infections by contact. The limited and conflicting nature of research on environmental surface materials poses a perplexing challenge to designers attempting to select materials to help control infection. It appears that for each general category of surfaces—flooring, upholstery, and wall finishes—no single material has yet been identified that consistently outperforms others across diverse performance criteria (e.g., harboring, capacity to transfer) and for different pathogens. This underscores the importance of selecting materials that are easily cleaned and of proper cleaning and disinfection procedures (Aygun et al., 2002; Barker, Vipond, & Bloomfield, 2004; Dettenkofer, Wenzler, et al., 2004; French et al., 2004; Griffiths, Fernandez, & Halcomb, 2002; Hota, 2004; Martinez, Ruthazer, Hansjosten, Barefoot, & Snydman, 2003; Neely et al., 2005; Wilson & Ridgway, 2006). As noted, some research suggests that latex paint with eggshell finish does not perform adequately in cleaning/disinfection for VRE and PSAE (Lankford et al., 2006). Detailed cleaning recommendations for environmental surfaces are available in the CDC/HICPAC guidelines (Sehulster et al., 2004).

Notwithstanding the importance of cleaning, there is alarming evidence indicating that conventional cleaning techniques often do not adequately eliminate contamination by serious pathogens such as MRSA and *C. difficile*. This problem has led infection control researchers to investigate the effectiveness of alternative decontamination methods or technologies, notably hydrogen peroxide vapor (HPV). French and colleagues (2004) conducted a prospective study of multibed patient rooms contaminated with MRSA in the United Kingdom, assigning six rooms to be cleaned using conventional methods and six similar rooms using HPV. Before cleaning, 70% of 359 sample swabs from the study rooms yielded MRSA. An important and disturbing finding was that following conventional cleaning, 66% of swabs taken from rooms decontaminated by traditional methods yielded MRSA, indicating that conventional cleaning failed to remove most MRSA contamination. By contrast, following HPV cleaning only 1.2% of swabs yielded MRSA, indicating that HPV was a far more effective method for decontaminating patient rooms (French et al., 2004). Another British study by Jeanes, Rao, Osman, and Merrick (2005) found that even after an exceptionally intensive three-day period of deep cleaning using traditional methods (detergent, steam cleaning, chlorine disinfectant), 16% of surfaces sampled in a Nightingale ward were still cultured with MRSA. Following HPV decontamination of the Nightingale ward, however, no MRSA at all was cultured from surfaces. These studies support the effectiveness of HPV cleaning and have implications for hospital architecture, because a key consideration in employing HPV is that no patients or staff can be in a room during the process of vapor decontamination. Accordingly, the use of HPV in multibed rooms or open bays necessitates temporarily removing all patients from the space, shutting and sealing the space for several hours, and disrupting patient care and flow. By comparison, evacuating persons from single-bed rooms following patient discharge poses little hindrance to using HPV.

Reducing Waterborne Infection Transmission

Compared with airborne and contact transmission of infection, fewer studies were identified on waterborne transmission in relation to hospital design factors. The literature nonetheless makes it clear that waterborne infections can be a serious threat to patient safety. Many bacterial and some protozoal micro-organisms can proliferate or remain viable in moist environments or aqueous solutions in healthcare settings (Sehulster et al., 2004). Anaissie, Penzak, and Dignani (2002) reviewed studies between 1966 and 2001 on waterborne nosocomial infections caused by micro-organisms other than *Legionella*. The review identified 43 reported outbreaks and an estimated 1,400 deaths each year in the United States alone resulting from waterborne nosocomial pneumonia caused by *Pseudomonas aeruginosa*. A study of 115 randomly selected dialysis facilities in the United States detected nontuberculous mycobacteria in 83% of centers (Carson et al., 1988). Contaminated water systems in healthcare settings (such as inadequately treated wastewater) may lead to the pollution of municipal water systems, enter surface or ground water, and affect residents (Iversen et al., 2004).

Sources and Environmental Routes of Waterborne Transmission

The CDC/HICPAC guidelines (Sehulster et al., 2004) identify the following categories of environmental routes or sources of waterborne transmission: (1)

direct contact, such as hydrotherapy (Angenent et al., 2005); (2) ingestion of water, such as drinking water (Conger et al., 2004; Squier, Yu, & Stout, 2000); (3) inhalation of aerosols dispersed from contaminated water sources, such as improperly cleaned or maintained cooling towers, showers (Mineshita, Nakamori, Seida, & Hiwatashi, 2005), respiratory therapy equipment, and room air humidifiers; and (4) aspiration of contaminated water.

Environmental Approaches to Reduce Waterborne Infection Transmission

Based on our literature review, the following environmental approaches that aid in controlling and preventing waterborne infections were identified.

Water supply system. The water supply system should be designed and maintained with proper temperature and adequate pressure; stagnation and back flow should be minimized; and dead-end pipes should be avoided (AIA and FGI, 2006; Sehulster et al., 2004). To prevent the growth of Legionella and other bacteria, the CDC/HICPAC guidelines recommend that healthcare facilities maintain cold water at a temperature below 68°F (20°C), store hot water above 140°F (60°C), and circulate hot water with a minimum return temperature of 124°F (51°C) (Sehulster et al., 2004). When the recommended standards cannot be achieved because of inadequate facilities that cannot be renovated, other measures such as chlorine treatment, copper-silver ionization, or ultraviolet lights are recommended to ensure water quality and prevent infection (Sehulster et al., 2004). For example, in a university hospital where endemic nosocomial legionellosis was present and all previous disinfection measures had failed, the implementation of a copper-silver ionization system substantially decreased environmental colonization by Legionella, and the incidence of nosocomial legionellosis decreased dramatically (Modol et al., 2007). The review by Anaissie and colleagues (2002) recognized the potential severity of waterborne infections and recommended that high-risk patients should not be exposed to tap water, but should use sterile water instead.

Point-of-use fixtures. Water fixtures such as sinks, faucets, aerators, showers, and toilets have been identified as potential reservoirs for pathogenic microorganisms (Blanc et al., 2004; Conger et al., 2004; Mineshita et al., 2005; Squier et al., 2000). Such fixtures produce aerosols that can disperse microbes, and they have wet surfaces on which molds and other micro-organisms can proliferate. However, empirical evidence linking these fixtures to nosocomial infections is still limited; no consensus has been reached regarding the disinfection or removal of these devices for general use (Sehulster et al., 2004). Regular cleaning, disinfection, and good maintenance should be provided, especially in areas housing immunocompromised patients.

Decorative fountains in healthcare settings. Decorative fountains increasingly are being used by designers for healthcare facilities, because they can serve as landmarks and wayfinding elements as well as positive distractions that reduce stress (Joseph, 2006). The infection control departments of some hospitals may oppose the installation of fountains out of concern for the possible generation of infectious aerosols. However, Rogers' review (2006) found no empirical study linking a waterborne infectious disease or nosocomial outbreak to the indoor placement of a water fountain or water feature in hospitals. The only related case was an outbreak of Legionnaires' disease among a group of older adults in a hotel. The source was traced to a fountain in the lobby, which was not regularly maintained and which was heated by underwater lighting (Hlady et al., 1993). Despite the absence of empirical documentation linking properly maintained fountains to hospital-acquired infections, the AIA & FGI Guidelines (2006) recommend that fountains not be installed in enclosed spaces in hospitals.

Reducing Multiroute Transmission by Means of Single-Bed Rooms and Increased Isolation

Thus far the three routes of infection transmission have been examined and discussed separately. In reality, these three routes often intertwine, and environmental approaches may influence more than one transmission route. This research team has found credible evidence for the multiroute impact of single-bed rooms and increased isolation in infection control. Therefore, we have opted to present this information in a separate section instead of within the previous sections addressing individual transmission routes.

Several literature review articles have supported the association between single-bed rooms and reduced infection rates, including Dettenkofer, Seegers, et al.'s (2004) review on the relationship between architectural design and nosocomial infections and Chaudhury, Mahmood, and Valente's review (2005) on the advantages and disadvantages of single-versus multibed accommodations. Also, Calkins and Cassella (2007) surveyed research on nosocomial infections in nursing homes and similarly concluded that private bedrooms reduce the risk of infection as compared to shared bedrooms. The present review conducted a broader, updated survey and analysis, and evaluated not only environment-infection *associations,* but also the underlying *mechanisms* that could plausibly account for these associations.

Effect of single-bed rooms in reducing airborne infection. Because infected patients carry airborne pathogens into patient rooms and nursing units, it is important to ensure sufficient isolation capacity for such patients to prevent the spread of pathogens. Providing single-bed rooms increases isolation capacity; facilitates filtration, ventilation, and airflow control (e.g., negative room pressurization); and by these well-established measures or mechanisms, it plays a key role in preventing a patient with an aerial-spread infection from infecting others and protects immunocompromised patients in nearby rooms from airborne pathogens. As might be expected, studies of cross-infection for contagious airborne diseases (such as influenza, TB, measles, and chickenpox) have revealed that placing patients in single rooms (Ben-Abraham et al., 2002), single-bed cubicles with partitions (Gardner, Court, Brocklebank, Downham, & Weightman, 1973), isolation rooms (Mulin et al., 1997), or rooms with fewer beds and more space between patients (McKendrick & Emond, 1976) is safer than housing them in multibed spaces with more patients. Vonberg and Gastmeier (2005) reviewed literature on the isolation of cystic fibrosis patients, for whom respiratory tract infections contributed markedly to morbidity and mortality. They found in 31 out of 39 studies that cross-infection of *Pseudomonas aeruginosa* had been halted by isolating patients. Research on burn patients and other vulnerable or immunosuppressed patient groups provides strong evidence that single rooms in combination with air filtration substantially reduce the incidence of infection and mortality (McManus, Mason, McManus, & Pruitt, 1994; Passweg et al., 1998; Shirani et al., 1986). In a study of nursing homes, Drinka, Krause, Nest, Goodman, and Gravenstein (2003) found that roommates of persons infected with influenza had a 3.07 higher relative risk of acquiring the illness than did individuals assigned to single-bed rooms.

Although MRSA is spread mainly by contact, it has been known for decades that patients with *Staphylococcus aureus* infections shed skin scales contaminated with the pathogen, which become suspended throughout the air in rooms and which can spread the infection to other patients sharing that space. Lidwell et al. (1970) documented a significantly reduced rate of nasal acquisition of *Staphylococcus aureus* for patients in single-bed rooms than for those in multibed rooms. Shiomori and colleagues (2002) found that in rooms with a MRSA patient, the air concentration of MRSA-contaminated skin scales reached 116 per cubic foot, representing an added risk of airborne transmission to uninflected patients.

The SARS outbreaks in Asia and Canada highlighted dramatically the failings of multibed rooms for controlling or preventing infections among both patients and healthcare workers. SARS is transmitted by droplets that can be airborne over a limited area. The point should be emphasized that SARS in Canada was predominantly a *hospital-acquired*—not a community-acquired—infection, because approximately 75% of SARS cases resulted from exposure in hospital settings (Farquharson & Baguley, 2003). In Canadian and Asian hospitals, the pervasiveness of multibed spaces in emergency departments (EDs) and ICUs worsened SARS cross-infection. Furthermore, the scarcity of isolation rooms with negative pressure was a serious obstacle to implementing effective treatment and control measures. Toronto hospitals were forced, on a crisis basis, to construct hard wall partitions with doors to replace curtain partitions between beds in multibed spaces, and to implement airflow and pressure adaptations in EDs and ICUs to create many additional negative-pressure isolation rooms with HEPA filtration (Farquharson & Baguley, 2003).

Effect of single-bed rooms in reducing contact transmission. The use of single-bed rooms instead of multibed rooms also helps to control infections spread by contact. Single-bed rooms can *facilitate cleaning and decontamination*. As discussed earlier, many surfaces and features near infected patients quickly become contaminated, creating numerous reservoirs that can transfer pathogens to patients and staff. Given the vital importance of cleaning for the removal of contamination, one advantage of single-bed rooms compared to multibed rooms is that they are easier to clean and decontaminate thoroughly after a patient is discharged. In certain countries, when a patient has been discharged from a multibed room, cleaning staff are not permitted to clean electrical equipment or anything attached to other patients remaining in the space, thus increasing the risk of cross-infection (Ulrich & Wilson, 2006). Scrupulous cleaning of double rooms, or the four-bed and six-bed spaces prevalent in many countries, often entails the disruptive and costly temporary removal of all patients from these rooms. In addition, as mentioned in an earlier section, even when conventional cleaning methods are used according to prescribed protocols or the manufacturers' instructions, extensive contamination by pathogens such as MRSA still remains on surfaces (French et al., 2004; Jeanes et al., 2005). If more effective cleaning techniques such as HPV are used, multibed rooms present additional challenges because all patients in the room must be transferred to other spaces during the vaporization treatment.

Single-patient rooms may also help to *improve hand-washing* compliance and thereby contribute to infection control. Some studies offer evidence that when all single-bed rooms are furnished with a conveniently located sink in each, the nosocomial infection rates in ICUs and burn units diminish, as compared to when the same staff and comparable patients are in multibed open units with few sinks (Goldmann, Durbin, & Freeman, 1981; McManus et al., 1994; McManus, McManus, Mason, Aitcheson, & Pruitt, 1985; Mulin et al., 1997). Although these studies did not measure hand-washing frequency, the investigators posited that increased hand washing was an important factor in reducing infections in the units with single-patient rooms and more sinks.

In several studies documenting the positive association between single-bed rooms and reduced infection rates, the reduction in contact transmission (such as via reduced contamination of surfaces) was not directly measured, but it might have played an important role, based on previous knowledge. For example, MRSA is spread mainly by contact. Single-bed rooms appeared to reduce or prevent MRSA infections compared to multibed rooms in various healthcare settings, including 212 ICUs across Germany (Gastmeier, Schwab, Geffers, & Ruden, 2004), 173 hospitals across Europe (MacKenzie et al., 2007), a U.K. hospital with 1,100 beds (Wigglesworth & Wilcox, 2006), and a NICU in the United States (Jernigan, Titus, Groschel, GetchellWhite, & Farr, 1996). Also, having a roommate has been identified as a risk factor for nosocomial diarrhea and gastroenteritis (Chang & Nelson, 2000; Pegues & Woernle, 1993). Ben-Abraham and colleagues (2002) found that nosocomial infection frequency was much lower in a single-bed pediatric intensive care unit (PICU) than in a unit with multibed rooms and comparable patients, and they tentatively concluded that single-bed rooms helped to limit the person-to-person spread of pathogens among patients. Although the pattern of results across studies on balance strongly suggests that single rooms reduce infection, Preston, Larson, and Stamm's (1981) finding is anomalous in that it found single-bed ICU isolation rooms were associated with only a slight, insignificant reduction in infection rates compared to multibed rooms.

Several deadly outbreaks of *C. difficile* in North American and European hospitals and thorough published investigations have underscored powerfully the threat to patient safety posed by multibed rooms. A highly virulent infection characterized by diarrhea and colitis, in several countries *C. difficile* causes more deaths than MRSA. The infection is spread mainly by contact, and *C. difficile* spores can be viable for months on environmental surfaces (Kramer, Schwebke, & Kampf, 2006). Two outbreaks in the United Kingdom at two National Health Service hospitals have caused approximately 40 deaths (Healthcare Commission, 2006) and 90 deaths (Healthcare Commission, 2007), respectively. The investigations in these hospitals identified a predominance of multibed rooms with shared toilets, and a scarcity of single rooms with private toilets as key factors that prevented the timely isolation of patients and contributed to the spread of *C. difficile* and the duration and high mortality of these outbreaks (Healthcare Commission, 2006, 2007). Another study has also reported that single-bed isolation helped prevent the spread of *C. difficile* (Malamou-Ladas, O'Farrell, Nash, & Tabaqchali, 1983).

Single rooms, admission, and proactive separation of patients. Providing a high proportion of single rooms in hospitals conveys a major safety advantage, because it enables *separation of patients upon admission* and makes it possible to prevent cross-infection from unrecognized carriers of pathogens (Ulrich & Wilson, 2006). Even if patients are screened for MRSA, *C. difficile,* or other pathogens immediately upon admission, processing test results often requires two or three days, during which time environmental surfaces in the rooms of infected patients quickly become extensively contaminated, creating pathogen reservoirs that will be touched by staff and possibly by patients (e.g., French et al., 2004). Accordingly, assigning an unidentified carrier initially to a multibed room heightens the risk of cross-infection. By the time test results revealing that the patient is colonized or infected are available, it may be too late to isolate the individual, because transmission to one or more roommates may already have occurred. A prospective study by Cepeda et al. (2005) screened patients for MRSA when they were admitted and placed in multibed rooms in the ICUs of two London hospitals. Patients who proved to be MRSA-positive (after a 3-day delay for testing) were assigned either to be moved into isolation or to remain in their multibed rooms. Findings indicated that moving patients to single-bed rooms after testing positive for MRSA did not reduce cross-infection to other patients (Cepeda et al., 2005), supporting the interpretation that the contamination of surfaces and/or the spread of the infection to roommates occurred in the period prior to isolation.

Single-bed rooms may also help manage the *growing problem of community-acquired infection*. MRSA and other serious multidrug resistant infections are no longer confined to healthcare settings, but are increasingly widespread and endemic in communities internationally. According to a study by the U.S. CDC, 13.7% of MRSA infections in 2005 originated in the community (Klevens et al., 2007b). Another 58.4% of MRSA infections in the United States were *community-onset*, or manifested themselves outside the hospital, but had a healthcare link, such as a patient history of surgery, hospitalization, or residence in a long-term care facility. Hospital-onset MRSA infections accounted for only 26.6% of the cases. These findings imply that mounting numbers of people admitted to the hospital as inpatients, or who visit EDs or ambulatory clinics for care, will be carriers of serious community-acquired or community-onset infections. The difficult and escalating infection control challenge for hospitals that is posed by community-acquired and community-onset infections is reflected, for example, in the fact that MRSA has become the most common cause of skin and soft-tissue infections among patients presenting to EDs in U.S. cities (Moran et al., 2006). Furthermore, the growing trend toward the spread of antibiotic-resistant pathogens in communities will inevitably continue as sicker, more vulnerable patients are cared for at home or in long-term care facilities, and as they receive frequent and prolonged courses of antibiotics (Ulrich & Wilson, 2006). Against this background, in the future hospitals may need to screen and assign all inpatients to single rooms upon admission to prevent infections from spreading to other patients. Apart from MRSA, the spread of infections such as *C. difficile* in communities implies that single rooms with toilets and good air quality will increasingly be needed in EDs and outpatient surgery clinics as well as in inpatient units.

Reducing Medical Errors

Summary of Evidence and Recommendations

Like hospital-acquired infections, medical errors pose serious threats to patient safety. This research team identified several rigorous studies linking environmental factors with medical errors. The limited literature shows that medical errors are not caused only by the mistakes of a few individuals, but by a combination of both people and the environment, and that environmental approaches can play an important role in reducing errors.

Environmental factors discussed in relation to medical errors include *noise, light,* and *acuity-adaptable, single-patient rooms.* There is limited evidence that prescription error rates increase sharply when there is an interruption or distraction from an unpredicted noise (e.g., a telephone call) (Flynn et al., 1999; Kistner, Keith, Sergeant, & Hokanson, 1994). Poor lighting levels can also affect the performance of healthcare workers and lead to medical errors. One study has shown significantly lower rates of medication-dispensing errors when the lighting level for work surfaces is sufficiently high (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991). Further, as demonstrated by empirical studies (Hendrich, Fay, & Sorrells, 2002, 2004), the use of acuity-adaptable rooms can substantially reduce possible sources of medical error (such as transfers, delays, communication discontinuities among staff, loss of information, and changes in computers or systems), and thereby lower error rates. Additional research is needed to further confirm the findings of limited previous studies, and to identify ways to design better working environments that may reduce or prevent medical errors.

Severity and General Causes of Medical Errors

The IOM (1999) estimates that 44,000 to 98,000 people die each year of preventable medical errors, based on annual percentages derived from two major studies and the annual hospital admissions rate of 1997. Even the lower estimate is more than the number of annual deaths caused by motor vehicle accidents (43,458), breast cancer (42,297), or AIDS (16,516). The report also draws attention to the total cost of medical errors in addition to the lives lost (including the expense of additional care necessitated by the errors, lost income and household productivity, and disability), which is estimated to range between $17 billion and $29 billion per year in hospitals nationwide (Kohn, et. al., 1999).

Medical errors can include a range of adverse events, including physical errors made during surgical procedures, incorrect diagnoses, and medication errors. Errors are generally triggered by a combination of active failures and latent conditions. *Active failures* are caused by the unsafe performance of caregivers or by the system through lapses, mistakes, and procedural violations. *Latent conditions* are established by designers, builders, and top level management and they make errors more likely. Examples of latent conditions caused by management include work overload, staff shortage, and inexperience with working conditions. Latent conditions related to design include noise, lack of space, and other design failures.

Impact of Noise on Medical Errors

Unpredictable loud noise can distract people and interrupt their performance. A large number of studies have documented the negative impact of noise on workers' performance in nonhealthcare settings, and unpredictable noises disrupt task performance more than predictable ones. Additionally, noise has a greater negative impact when tasks are more complicated (Leather, Beale, & Sullivan, 2003). The combination of unpredictable noise and complicated tasks can increase errors in calculation, tracking, and monitoring tasks, and lead to slower learning and poor memorization (Sundstrom & Sundstrom, 1986).

However, these findings have not been fully explored yet in healthcare settings. A number of studies investigated the contribution of auditory factors, such as high levels of ambient noise (80 dB–85 dB), different types of music (classical or rock), and auditory distractions in the occurrence of surgical and diagnostic errors (Goodell, Cao, & Schwaitzberg, 2006; Moorthy, Munz, Undre, & Darzi, 2004; Sanderson et al., 2005; Zun & Downey, 2005) and found no significant evidence of their effects. However, most of these studies have been conducted in experimental settings by carrying out simulated tasks and/or with simulated noises. Additional research is needed to test the impact of different auditory factors under real-life conditions.

There is some evidence regarding the impact of interruptions or distractions on medication-dispensing errors by hospital pharmacists (Flynn et al., 1999; Kistner et al., 1994). They found that error rates for prescriptions increased sharply when there was an interruption or distraction, including unexpected noises (e.g., a telephone call).

Impact of Lighting Level on Medical Errors

Many studies in nonhealthcare settings have demonstrated that performance and errors can be affected by lighting level as well as noise. Such poor performance in healthcare settings may lead to medical errors. Sundstrom and Sundstrom (1986) found that visual inspection task performance declined when light is not bright enough. A large-scale study in pharmacy examined the effects of different illumination levels on pharmacists' prescription-dispensing errors, and it strongly suggested that the frequency of such errors was reduced when work-surface light levels were relatively high (Buchanan et al., 1991). It evaluated the error rate under three different illumination levels, including 450 lux, 1,100 lux, and 1,500 lux. Results showed that medication-dispensing error rates were significantly lower (2.6%) at an illumination level of 1,500 lux, compared to an error rate of 3.8% at 450 lux.

Reducing Patient Transfers by Means of Acuity-Adaptable Rooms

The transfer of patients between rooms or units is a source of medical error (Cook, Render, & Woods, 2000; Ulrich & Zhu, 2007). Reasons for these errors include delays, communication discontinuities among staff, loss of information, and changes in computers or systems. A possible solution is to create an acuity-adaptable care process and to provide patient rooms that substantially reduce transfers. When the Methodist Hospital in Indianapolis, Indiana, changed its coronary ICUs from two-bed rooms to acuity-adaptable single-bed rooms, transfers were reduced by 90% and medication errors were lowered by 67% (Hendrich, Fay, & Sorrells, 2002, 2004). Reducing transfers also saves staff time, shortens patient stays, and reduces cost (IOM, 2004). Single-patient rooms, even nonacuity-adaptable ones, have been associated with better staff communication, less patient transfer, fewer medical errors, and lower infection rates as compared to multibed patient rooms (Chaudhury, Mahmood, & Valente, 2006). Additional studies and demonstration projects are needed to ascertain the safety advantages of acuity-adaptable, single rooms for other types of units and patient categories.

Reducing Patient Falls

Summary of Evidence and Recommendations

There is a large literature that examines the causes and risk factors involved in patient falls in hospitals. This is an area of great importance, because patients who fall incur physical injuries and adverse psychological effects and have greater lengths of stay in the hospital (Brandis, 1999). Among elderly persons (more than 65 years old), most falls occur in hospitals and nursing homes, where the rate of falls reaches 1.5 per bed annually, which is almost three times the rate for community-dwelling elderly persons (American Geriatrics Society, 2001). It is estimated that the total cost of fall injuries for older people was $20.2 billion per year in the United States in 1994, and that it would reach $32.4 billion (in 1994 U.S. dollars) in 2020 (Chang, Morton, Rubenstein, & Mojica, 2004).

Although the role of the environment in causing or preventing patient falls is widely accepted, there is no conclusive evidence linking environmental interventions with reduced falls. Studies have sought to identify the design issues that might have contributed to falls (such as the placement of doorways, handrails, and toilets), but no studies have compared different design options to determine the independent impact of a single design factor on the incidence of falls. One study has provided some promising findings, suggesting that decentralized nurse stations can reduce falls; but more research in more rigorous studies is needed to confirm these findings and to identify all the variables involved. Several studies have clearly shown that despite a popular misconception, bedrails do not reduce the rate of falls and can, in fact, increase the severity of falls.

Causes and Locations of Patient Falls

Previous studies have examined the locations of fall incidents retrospectively or discussed environmental-modification programs, such as improving lighting, securing carpeting, and so on. However, a meta-analysis and systematic review of randomized controlled trials of fall-prevention interventions found that there was no clear evidence for the independent effectiveness of environmental-modification programs (Chang et al., 2004). Nonetheless, several studies have indicated that most patient falls occur in the bedroom, followed by the bathroom, and that comprehensive fall-prevention programs can have a positive effect. Brandis (1999) reported transfers to and from bed as the cause of 42.2% of inpatient falls. In another study, a group of researchers analyzed 1-year fall data (267 falls), and reported that 38% of the falls occurred during transfers to and from bed and 16.1% during toileting (Tan et al., 2005). Brandis (1999) reported design shortcomings in the bathroom and bedroom areas, including slippery floors, inappropriate door openings, poor placement of rails and accessories, and inappropriate heights of toilet and furniture. After the fall-prevention program (which included identification of high-risk patients, management strategies, environmental and equipment modification, and standardization) was implemented, there was an overall decrease in falls of 17.3%. Thus, fall-prevention strategies that include environmental modification have worked in the past. But it is not clear how much the effectiveness of such strategies can be attributed to environmental factors alone.

Unit Configuration

An innovative and promising environmental strategy for reducing falls has its origins in evidence that suggests that many falls occur when patients attempt to get out of bed unassisted or unobserved (Uden, 1985;

Vassallo, Azeem, Pirwani, Sharma, & Allen, 2000). To facilitate the observation of patients and the provision of timely assistance, Methodist Hospital in Indianapolis, Indiana, renovated a coronary critical care unit from centralized nurse stations with two-bed rooms to decentralized nurse stations with large single-bed rooms. These changes resulted in families being present more often and therefore being available to help patients or call for aid when needed, in addition to other positive impacts (Hendrich et al., 2002, 2004). A comparison of data from 2 years prior and 3 years after the renovation showed that falls were cut by two-thirds—from six falls per thousand patients to two per thousand. Given that falls are a critical safety problem, additional research is needed to understand more completely the effectiveness of this approach and its implications for designing safe patient-care units that reduce patient falls.

Bedrails

Although there is a common conception that bedrails prevent falls and reduce injuries, there is considerable evidence demonstrating that bedrails are *ineffective* for reducing falls and may actually increase the severity of injuries caused by falls from bed (Capezuti, Maislin, Strumpf, & Evans, 2002; Hanger, Ball, & Wood, 1999; Leeuwen, Bennett, West, Wiles, & Grasso, 2001; Talerico & Capezuti, 2001; Tan et al., 2005). Examining the one-year incident reports from a 730-bed university teaching hospital, a group of researchers found that 55% of the restrained falls resulted in injury; 11.8% of bed-area falls and 27.8% of all bedside injuries were associated with bedrails (Tan et al., 2005). They also found that the restrained falls resulted in more severe injuries. In his commentary on the outcomes of bedrail use, O'Keefe (2004) cited the high rates of deaths within the bedrail-related incident reports of the U.S. Food and Drug Administration (228 deaths from 1985 to 1999), the Medical Devices Bureau of Canada (25 deaths from 1980 to 2000), and the Medical Devices Agency in the United Kingdom (15 deaths from 1995 to 2000), to further underline that bedrail use can lead to deaths.

Other studies on inpatient falls have focused on the factors associated with patients' physical, mental, medical, or cognitive conditions. Most of these studies examined the development and/or application of protocols for identifying risk factors for patient falls and corresponding interventions for their prevention, including organizational-, educational-, and practice-related interventions (Chang et al., 2004; Hendrich, 2003; Lyons, 2005; McCarter-Bayer, Bayer, & Hall, 2005; Stenvall et al., 2006; Suzuki et al., 2005; Walker, 2004).

RESULT II: IMPROVING OTHER PATIENT OUTCOMES THROUGH ENVIRONMENTAL MEASURES

Reducing Pain

Summary of Evidence and Recommendations

Pain is a pervasive and serious problem in hospitals. However, it is encouraging that mounting scientific evidence, including that from prospective randomized controlled studies, has shown that exposing patients to nature can produce substantial and clinically important alleviation of pain (Malenbaum, Keefe, Williams, Ulrich, & Somers, 2008; Ulrich, Zimring, Quan, & Joseph, 2006; Ulrich, 2008). Limited research also suggests that patients experience less pain when exposed to higher levels of daylight in contrast to lower levels of daylight in their hospital rooms. The state of knowledge on the environment-pain relationship has grown to the point where a leading international pain research journal recently published an article that emphasizes the importance of designing healthcare facilities to harness *nature, light,* and other environmental factors to enhance pain control (Malenbaum et al., 2008).

Regarding design measures to reduce pain, the research implies that patient rooms should be designed with large windows so that bedridden persons suffering from pain can look out onto sunny nature spaces.

Also, attention should be given to affording nature window views in procedure spaces, treatment rooms, and waiting areas where pain is a problem (Ulrich, 2008). Research also supports displaying visual art (paintings, prints, and photographs) with representational nature subject matter in healthcare settings where pain is experienced. Well-controlled randomized studies support providing technology (such as television screens and eyeglass displays) to simulate nature in spaces where patients undergo painful procedures and it is not feasible to provide distraction with actual nature. Nature simulations with both visual and auditory distraction may be more diverting and engrossing and hence more effective for relieving severe pain. Furthermore, pain theories and research findings imply that patients should not be placed in rooms or treatment spaces that lack nature distraction and contain environmental stressors such as noise, because pain may thereby be exacerbated (Malenbaum et al., 2008). Finally, the evidence implies that careful attention should be given to building orientation and site planning in healthcare projects, and that plans where some buildings block pain-relieving nature views and daylight from others should be avoided.

Effects of Nature Distraction on Pain

Viewing nature may decrease pain by eliciting positive emotions, reducing stress, and distracting patients from focusing on their pain (Malenbaum et al., 2008; Ulrich et al., 2006; Ulrich, 2008). According to distraction theory, pain requires considerable conscious attention. However, if patients become diverted by or engrossed in a pleasant distraction such as a nature view, they have less attention to direct to their pain, and the experienced pain therefore will diminish. The theory predicts that the more engrossing an environmental distraction, the greater the pain reduction (McCaul & Malott, 1984). This implies that nature distractions may be more diverting and hence effective in reducing pain if they involve sound as well as visual stimulation, and induce a heightened sense of immersion (Ulrich, 2008).

A study of matched patients recovering from abdominal surgery found that those assigned to rooms with a bedside view of nature (trees) had better postoperative recovery than matched patients assigned to identical rooms with windows overlooking the wall of a brick building (Ulrich, 1984). Patients with the nature view suffered substantially less pain, as indicated by their need for far fewer doses of strong pain medication than their counterparts with the wall view. In addition, the patients exposed to nature had shorter post-surgery stays, better emotional well-being, and fewer minor complications such as persistent nausea or headache (Ulrich, 1984). Another study prospectively and randomly assigned bedridden heart-surgery patients to view color pictures mounted in their line of vision (Ulrich, Lundén, & Eltinge, 1993). Patients assigned a picture of a spatially open, well-lighted view of trees and water needed fewer doses of strong pain drugs than patients exposed to abstract images or a control condition of no picture (Ulrich et al., 1993). A well-controlled prospective study by Tse, Ng, Chung, and Wong (2002) found that healthy volunteers in a hospital setting had a higher pain threshold and greater tolerance when they looked at a videotape of nature scenery.

As noted, theory predicts that nature exposures may be more engrossing and hence pain relieving when they involve sound as well as visual distraction. Lee and colleagues (2004) conducted a randomized prospective clinical trial on the effects of nature distraction on patients undergoing colonoscopy, and they found that visual distraction alone reduced pain but did not lower the intake of sedative medications. However, a combination of nature scenery with classical music reduced both pain and self-administered sedation during colonoscopy (Lee et al., 2004). Research on burn patients suffering from intense pain found that distracting individuals during burn dressings with a nature videotape accompanied by music lessened both pain and anxiety and stress (Miller, Hickman,

& Lemasters, 1992). A randomized clinical trial of patients undergoing painful bronchoscopy found that individuals assigned to look at a ceiling-mounted nature scene and listen to nature sounds (moving water, birds) reported less pain than a control group who looked at a blank ceiling during bronchoscopy (Diette, Lechtzin, Haponik, Devrotes, & Rubin, 2003). Kozarek and colleagues (1997) investigated the effects of seeing and listening to a nature travelogue on patients undergoing painful gastric procedures. Patient reports and nurse observations converged in suggesting that the combination of visual and auditory distraction improved comfort and tolerance for the procedures, as compared to a control condition without distraction (Kozarek et al., 1997). Other research suggests that a virtual reality audiovisual nature distraction (a walk through a forest with bird sounds) reduced discomfort and symptomatic distress in female chemotherapy patients (Schneider, Prince-Paul, Allen, Silverman, & Talaba, 2004).

Effects of Daylight Exposure on Pain

The presumed pain reduction mechanism for daylight is different than for nature. Sunlight exposure increases levels of serotonin, a neurotransmitter known to inhibit pain pathways. Walch and colleagues (2005) conducted a well-controlled prospective study of the effects of daylight on pain in patients undergoing spinal surgeries, who were admitted postoperatively to rooms either on the bright or shaded side of a surgical ward. Patients in the bright rooms were exposed to 46% greater sunlight intensity than those assigned to the more shaded rooms. Findings indicated that patients in rooms with more sunlight reported less pain and stress, and took 22% less analgesic medications, resulting in a 21% reduction in medication costs. It should be mentioned that the shaded patient rooms—and associated heightened pain—resulted when a new building was constructed and blocked sunlight from reaching this side of the facility.

Improving Patients' Sleep

Summary of Evidence and Recommendations

Hospitalized patients have an increased need for sleep because of their illnesses. However, in reality, they often suffer from diminished circadian rhythms and poor sleep while hospitalized (Southwell & Wistow, 1995), which may lead to increased stress (Novaes, Aronovich, Ferraz, & Knobel, 1997; Topf & Thompson, 2001), impaired immune function, ventilatory compromise, disrupted thermoregulation, and delirium (Wallace, Robins, Alvord, & Walker, 1999). These effects may hinder the healing process and contribute to increased morbidity and mortality (Krachman, Dalonzo, & Criner, 1995; Parthasarathy & Tobin, 2004).

The research team identified more than 70 articles about sleep in healthcare settings, including descriptive, correlational, and intervention studies. The literature confirmed that sleep disruption and deprivation were very common problems in healthcare settings, especially for high-acuity patients who are more susceptible to unfavorable environmental conditions. Environmental factors such as noise and light may result in electroencephalographic arousals and awakenings, and thereby fragment sleep and prevent patients from progressing into deeper and more restorative sleep stages (BaHammam, 2006).

Increased acoustic performance with reduced reverberation time and noise level increased sleep quality (Aaron et al., 1996; Topf, Bookman, & Arand, 1996).

Certain environmental approaches have shown promising results in improving patient sleep. First, single-bed rooms can reduce noise disturbance from roommates, visitors, and healthcare staff (Southwell & Wistow, 1995; Yinnon, Ilan, Tadmor, Altarescu, & Hershko, 1992), and thereby improve patient sleep (Gabor et al., 2003). Second, experimental studies support the installation of *high-performance sound-absorbing materials* to reduce reverberation time, sound propagation, and noise intensity levels, as well as to improve sleep (Berg, 2001; Hagerman et al., 2005; Philbin & Gray, 2002). Other noise reduction strategies such as adopting a noiseless paging system could also be considered. Furthermore, findings suggest that patient rooms should be carefully oriented and designed to receive natural daylight and maintain the normal light-dark cycle of 24-hour periods to help patients retain normal circadian rhythms and improve sleep (BaHammam, 2006; Wakamura & Tokura, 2001).

Quantity and Quality of Sleep in Healthcare Settings

Measurement of sleep. Sleep should be measured in terms of both quantity (such as total sleep time) and quality (such as the type and depth of sleep, the distribution over 24 hours, and other sleep architecture parameters) (Parthasarathy & Tobin, 2004). Even if total sleep time appears adequate, sleep quality may nonetheless be poor because of fragmentation and poor sleep architecture. Previous sleep studies have employed either subjective measures such as patients' self-reports (Sheely, 1996; Topf & Thompson, 2001; Tranmer, Minard, Fox, & Rebelo, 2003) or objective measures including direct observation (Kroon & West, 2000), polysomnography (PSG) (Freedman, Gazendam, Levan, Pack, & Schwab, 2001; Gabor et al., 2003; Singh, Mahowald, & Mahowald, 2004; Wallace et al., 1999), and bispectral index (Nieuwenhuijs, Coleman, Douglas, Drummond, & Dahan, 2002) or Actigraph (Kroon & West, 2000). Most studies have monitored sleep only at night, while some have focused on the 24-hour period and revealed that about half of the total sleep in acute care settings occurred during the daytime (BaHammam, 2006). We found it difficult to compare findings across studies because of the different measures used.

Sleep deprivation in different healthcare settings. Patient sleep has been studied more often in *high-acuity* units than other settings (BaHammam, 2006; Parthasarathy & Tobin, 2004; Redeker, 2000). Overall, high-acuity patients show sleep fragmentation, increases in stage 1 and stage 2 sleep, and decreases in more restorative stages—slow-wave and rapid eye movement sleep—as well as reductions in sleep efficiency (BaHammam, 2006; Parthasarathy & Tobin, 2004). In a survey study of 84 neurosurgery ICU patients, 79% of patients reported sleep disturbances (Ugras & Oztekin, 2007). In another survey of randomly selected ICU patients, sleep difficulty was identified as the second most important physical stressor, following pain (Novaes et al., 1997). Parthasarathy and Tobin (2004) reported that the number of sleep arousals and awakenings ranged from 20–68 per hour and varied across different acute care settings. Findings concerning total sleep time differ considerably across studies, ranging from normal or near normal sleep time at 7–10.4 hours a day (Freedman et al., 2001; Gottschlich et al., 1994), to decreased time at 3.6–6.2 hours per day (Aurell & Elmqvist, 1985; Gabor et al., 2003; Hilton, 1976). In a study of mechanically ventilated ICU patients using continuous PSG measurements, the mean total sleep time per 24-hour period was 8.8 ± 5.0 hours, the sleep-awake cycles were fragmented, and a mean of 57 ± 18% of total sleep time occurred during the day (Freedman et al., 2001).

General wards have been studied less frequently than high-acuity settings, and most studies have employed less reliable subjective measures, such as self-report surveys (Dogan, Ertekin, & Dogan, 2005; Kuivalainen, Ryhänen, Isola, & Meriläinen, 1998; Shafiq et al., 2006). Results strongly suggest that sleep deprivation is also a widespread problem among general ward patients. In a Finnish study, 65% of the medical and surgical patients reported sleeping badly in the hospital (Kuivalainen et al., 1998). Another study of medical and surgical patients in Canada found moderate to high disturbance scores for awakenings and soundness of sleep (Tranmer et al., 2003).

Sleep deprivation among different patient populations. Although most sleep studies have focused on adult populations, some have examined special populations, such as older people (Béphage, 2005;

Ersser et al., 1999; Vinzio, Ruellan, Perrin, Schlienger, & Goichot, 2003; Wakamura & Tokura, 2001), children and infants (Al-Samsam & Cullen, 2005; Corser, 1996; Cureton-Lane & Fontaine, 1997; Zahr & de Traversay, 1995), and specific groups, such as cardiac surgery patients (Simpson, Lee, & Cameron, 1996). In a study of PICU patients, children slept for a mean total of only 4.7 hours during the 10-hour night, with an average of 9.8 awakenings, and the mean length of a sleep episode was only 27.6 minutes (Cureton-Lane & Fontaine, 1997). In another study of 11 mechanically ventilated PICU patients, restorative sleep accounted for only 3% of total sleep time due to severe sleep fragmentation, as reflected in the high number of awakenings (Al-Samsam & Cullen, 2005).

Environmental Factors Affecting Sleep

A number of factors contribute to poor sleep in healthcare settings, including environmental factors like noise, light, and staff-patient interactions; physiological factors, such as the underlying disease and impact of medication; and the psychological characteristics of patients (BaHammam, 2006; Dogan et al., 2005; Reid, 2001). Environmental factors have been studied in several settings across different types of patients for their impact on sleep (Corser, 1996; Cureton-Lane & Fontaine, 1997; Freedman, Kotzer, & Schwab, 1999; Kuivalainen et al., 1998). In the Finnish study mentioned earlier, 80% of patients who reported poor sleep regarded environmental factors as the cause (Kuivalainen et al., 1998).

Impacts of noise. Environmental noise is one of the most important yet modifiable environmental factors affecting patients' sleep (Gabor et al., 2003; Meyer et al., 1994; Parthasarathy & Tobin, 2004; Schnelle, Ouslander, Simmons, Alessi, & Gravel, 1993; Topf & Davis, 1993; Topf & Thompson, 2001; Yinnon et al., 1992). In a survey of neurosurgery ICU patients, among those who reported sleep disturbance, 58% considered environmental noise a frequent disturbing factor (Ugras & Oztekin, 2007). Another study in an intermediate respiratory care unit showed a strong correlation between the number of high sound peaks (≥ 80 dBA) and arousals from sleep (Aaron et al., 1996). One study of ICUs suggested that about 20% of arousals and awakenings were related to noise, and 10% were related to patient care activities (Parthasarathy & Tobin, 2004). Topf and colleagues (1996) conducted a study with healthy volunteers in an experimental setting that replicated noise in ICUs and compared their sleep quality with that of control subjects who were not exposed to the ICU noise (Topf et al., 1996). Results showed that participants assigned to the ICU noise condition took longer to fall asleep, slept less, and experienced more awakenings and poorer sleep quality.

Impact of lighting conditions. In addition to noise, lighting is an important environmental factor affecting sleep/awake patterns (Béphage, 2005; Higgins, Winkelman, Lipson, Guo, & Rodgers, 2007). One study found that night lighting on wards was dimmed for a sleep duration that is no longer than that required by the average healthy person (Southwell & Wistow, 1995). This is a disturbing finding considering that patients need more sleep when they are ill and are more susceptible to sleep disturbances. Other research suggests that the inappropriate location, orientation, and design of patient rooms might reduce daylight exposure, diminish patients' circadian rhythms, and worsen their sleep at night (BaHammam, 2006; Wakamura & Tokura, 2001).

Environmental Approaches to Improve Sleep

Various interventions have been employed to improve patient sleep. Pharmacological assistance alone cannot achieve the desired quantity and quality of sleep in ICUs (Brown & Scott, 1998), not to mention its detrimental side effects. Environmental interventions have been developed to reduce environmental noise and disruptive staff-patient interactions at night, or to maintain the normal light-dark cycle of a day, and they have shown favorable results. Furthermore, some environmental interventions appeared to be more successful than organizational interventions like staff education or quiet hours (Gast & Baker, 1989; Moore et al., 1998; Walder, Francioli, Meyer, Lancon, & Romand, 2000).

Improving the acoustic environment. Certain environmental interventions have been found effective for reducing noise in hospital settings, including installing high-performance sound-absorbing ceiling tiles, eliminating or reducing noise sources (e.g., adopting a noiseless paging system), and providing single-bed rather than multibed rooms.

Installing high-performance sound-absorbing materials for environmental surfaces such as ceilings and walls can reduce reverberation time, sound propagation, and noise intensity levels (Berg, 2001; Hagerman et al., 2005; Philbin & Gray, 2002). Hagerman et al. (2005) examined the effects of sound-absorbing versus sound-reflecting ceiling materials in a coronary ICU by periodically changing the ceiling tiles. When the sound-absorbing tiles were in place, patient rooms showed a 5–6 dB drop in sound levels and a reduction in reverberation time from 0.8 to 0.4 second, indicating better acoustic conditions. Patients also reported fewer awakenings caused by noise. Further, Berg's research (2001) showed that even if the noise level (dB) remains almost the same, the reduction in reverberation time achieved by sound-absorbing ceiling tiles can improve sleep quality. Meanwhile, even relatively low decibel levels (27–58 dB), when coupled with longer reverberation times (sound-reflecting ceiling), significantly increased arousals in healthy volunteers sleeping in patient rooms. These findings have disturbing implications, because most hospitals have nighttime sound peaks exceeding those of the patient rooms in the study.

Providing single-bed rooms as opposed to multibed rooms can also lower noise levels and improve sleep quality. For multibed rooms in medium- and high-acuity units, most noises stem from the presence of other patients, whether caused by visitors, staff caring for other patients, or patient sounds such as coughing, crying out, and rattling bedrails (Southwell & Wistow, 1995; Yinnon et al., 1992). One study of multibed bays in a children's hospital concluded that noise levels were so high that consideration should be given to abolishing open-bay rooms (Couper et al., 1994). These findings also have important implications for patient sleep, because noises stemming from the presence of other patients can be the major cause of sleep loss in multibed rooms, (Southwell & Wistow, 1995; Yinnon et al., 1992). In the Finnish study mentioned previously, the presence of other patients was reported as one of the most disturbing factors (Kuivalainen et al., 1998). Gabor and colleagues (2003) compared the effect of open areas and single rooms on noise levels and the sleep of six healthy volunteers in an ICU. The average noise level was higher (51 dB) in the open ICU than in the single room (43 dB), as were the respective peak levels (65 dB versus 54 dB). Furthermore, total sleep time in the single-bed room (9.5 hours) was greater than that in the open ICU (8.2 hours), although the number of arousals was similar in both settings.

Avoiding light pollution. One study examined the impact of simulated bright daylight in a north-facing room with limited natural light, affixing to the bed a lamp that was turned on at 10:00 a.m. and off at 5:00 p.m. (Wakamura & Tokura, 2001). Findings suggested that hospitalized elderly patients experienced better deep sleep at night when they were exposed to the artificial diurnal daylight compared to when they had darker daytime conditions. However, not all light-related interventions are successful. Another intervention study implemented guidelines to control nighttime light levels, and this resulted in significantly lower mean light disturbance intensity and shorter periods with high light levels (Walder et al., 2000). However, these changes were accompanied by greater variation in light levels, which could disturb patients' sleep patterns. More research is needed to better understand how both daytime and nighttime light environments can be optimized to improve sleep. Design details such as flexible light controls with various lighting intensities might be considered.

Directions for Future Research

Despite emerging evidence, gaps in our knowledge still remain. To better understand the independent effect of environmental interventions, future research should control effectively for other variables that influence sleep, such as acuity of illness, sedation level, pain, and disruptive patient-care procedures. Longitudinal designs with larger numbers of patients should be developed and employ standard sleep measures over 24-hour periods rather than at night only.

Reducing Patient Stress

Summary of Evidence and Recommendations

Stress experienced by patients is an important negative outcome, which directly and adversely affects many other healthcare outcomes. If hospital physical environments contain stressful features or characteristics such as noise, patient stress and other outcomes will often be worsened. By contrast, hospital design that minimizes environmental stressors and fosters exposure to stress-reducing or restorative features should advance improved outcomes (Ulrich 1991; Ulrich et al., 2006).

Our literature review identified certain environmental features that can *reduce stress* and improve outcomes. Several well-controlled experimental studies have generated strong evidence that real or simulated views of nature can produce substantial restoration from psychological and physiological stress within a few minutes. Other studies using self-report methods and behavioral observation suggest that *gardens* in hospitals can reduce stress among patients and families by providing nature distraction and fostering social support. Based on these findings, it is recommended that hospital siting and design should provide restorative window views of nature and gardens from patient rooms and other interior areas where stress is a problem. Additionally, limited research on hospital *art* suggests that the great majority of patients prefers and responds positively to representational nature art, but that abstract or ambiguous art can elicit stressful reactions in many patients.

Considerable research has shown that noise is a pervasive stressor that elevates psychological and physiological stress in patients, and worsens other outcomes. Research also indicates that hospital noise levels around the world have been rising steadily since the 1960s. Therefore, a high priority should be placed on creating much quieter environments when constructing or renovating hospitals. As mentioned in another section (Improving Patients' Sleep), research has identified effective environmental approaches for quieting healthcare settings, the most important of which appears to be providing single-bed rooms. Other noise-reducing measures supported by research include insulating or eliminating noise sources (e.g., replacing overhead paging with a noiseless system) and installing high-performance sound-absorbing materials on ceiling and wall surfaces.

Stress as a Major Problem in Healthcare Facilities

Much research has confirmed that hospitalized patients experience stress, and that a large proportion suffers from acute stress. Many stressors are unavoidable accompaniments of illness and medical treatments, but others result from shortcomings in the culture of healthcare organizations. Additional stress is produced by poorly designed physical environments. In addition to afflicting patients, stress is a major burden for their families (Ulrich, 1991; Ulrich et al., 2006).

The stress experienced by a patient is an important negative outcome in itself, and it directly and adversely affects many other outcomes. These unhealthy effects are related to detrimental psychological, physiological, neuroendocrine, and behavioral changes associated with stress responses (Gatchel, Baum & Krantz, 1989; Ulrich, 1991). The neuroendocrine component, for example, elevates levels of a natural steroid, cortisol, and releases stress hormones that tax the heart and other major organs. Importantly, much research has shown that stress responses suppress immune system functioning through their effects on neuroendocrine activity and the central nervous system (Kiecolt-Glaser, et al., 1987). Stress-related immune impairment decreases resistance to infection and worsens recovery outcomes such as wound healing (Cohen, Tyrrell, & Smith, 1991; Kiecolt-Glaser et al., 1995).

Reduce Stress by Controlling Noise

Noise levels and sources in hospitals. The World Health Organization (WHO) provides guideline values for continuous background noise in hospital patient rooms, which are 35 dBA during the day and 30 dBA at night, with nighttime peaks in wards not to exceed 40 dBA (Berglund, Lindvall, & Schwela, 1999). However, much research has shown that actual background and peak noise levels fall in far higher ranges, and a review of 35 studies concluded that hospital noise levels around the world have been rising consistently since the 1960s (Busch-Vishniac et al., 2005). Background noise levels typically are 45 dB to 68 dB, with peaks frequently exceeding 85 dB to 90 dB (Aaron et al., 1996; Allaouchiche, Duflo, Debon, Bergeret, & Chassard, 2002; Balough, Kittinger, Benzer, & Hackl, 1993; Blomkvist, Eriksen, Theorell, Ulrich, & Rasmanis, 2005; Cureton-Lane & Fontaine, 1997; Falk & Woods, 1973; Guimaraes et al., 1996; Hilton, 1976; Homberg & Coon, 1999; Kent, Tan, Clarke, & Bardell, 2002; McLaughlin, McLaughlin, Elliott, & Campalani, 1996; Robertson, Cooper-Peel, & Vos, 1998). In evaluating these noise levels, it should be noted that the decibel scale for quantifying loudness or sound pressure intensity is logarithmic; each 10 dBA increase therefore represents a sound pressure level that is 10 *times* higher.

Medical equipment and staff voices often produce noise at 70–75 dB levels at the patient's head, which approach the noise level in a busy restaurant (Blomkvist et al., 2005). Noises from alarms and certain equipment (e.g., a portable X-ray machine) exceed 90 dB, which is comparable to walking next to a busy highway when a motorcycle or large truck passes. A study in a NICU measured peak levels once per minute and found that 31% of peaks exceed 90 dB (Robertson et al., 1998). One study even recorded 113 dB during shift changes at a large hospital (Cmiel, Karr, Gasser, Oliphant, & Neveau, 2004). OR noises from drills, saws, and other equipment are in the range of 100–110 dB, presenting a significant risk for noise-induced hearing loss (Hodge & Thompson, 1990; Love, 2003; Nott & West, 2003).

Our review of the research identified at least three major reasons why hospitals are excessively noisy and therefore stressful (Ulrich, 2003). First, as mentioned previously, the sources of noise are unnecessarily numerous and loud. Well-documented examples include staff voices, paging systems, alarms, bedrails moved up or down, telephones, ice machines, pneumatic tubes, and trolleys. Second, many environmental surfaces (e.g., floors, ceilings, walls) are hard and sound-reflecting, not sound-absorbing; this creates poor acoustic conditions (long reverberation times) that enable noise to echo, linger, and propagate over large areas and into patient rooms (Blomkvist et al., 2005; Ulrich, 2003). Finally, hospitals are noisy because many patients are housed in multibed rooms in which much noise originates from other patients (Baker, 1984; Southwell & Wistow, 1995; Yinnon et al., 1992).

Effects of noise on patient stress and other outcomes. Another section in this report, Improving Patients' Sleep, surveys research showing that noise is a major cause of awakenings and poor sleep. In addition to worsening sleep quality, noise elevates psychological and physiological stress in patients, as indicated by negative feelings such as anxiety and annoyance (Bentley, Murphy & Dudley, 1977; Haslam, 1970; Hilton, 1976; Synder-Halpern, 1985) and detrimental physiological changes such as elevated heart rate and blood pressure (Baker, 1992; Morrison, Haas, Shaffner, Garrett, & Fackler, 2003). A prospective study by Hagerman et al. (2005) examined the effects of sound-reflecting versus sound-absorbing tiles on coronary intensive care patients. When the sound-absorbing ceiling tiles were in place, patients evidenced lower physiological stress (lower sympathetic arousal), slept better, reported better care from nurses, and had a lower incidence of rehospitalization in the weeks following discharge. Other studies have focused on infants in NICUs, finding that higher noise levels elevate blood pressure, heart, and respiration rates, and decrease oxygen saturation, thereby increasing the need for oxygen support therapy (Slevin, Farrington, Duffy, Daly, & Murphy, 2000; Zahr & de Traversay, 1995).

Environmental approaches to reduce noise and stress. The foregoing discussion makes it clear that hospitals are far too noisy, and that noise in combination with acoustically poor environmental surfaces and multibed patient rooms worsens stress and other outcomes. As discussed in detail in an earlier section (Improving Patients' Sleep), there are effective environmental approaches available to quiet healthcare settings, which can be more successful than organizational interventions such as staff education or establishing quiet hours (Gast & Baker, 1989; Moore et al., 1998; Walder et al., 2000).

The most important design measure to reduce noise for inpatients appears to be single-bed rooms. In this regard, the research literature indicates that noise levels are lower in single- than multibed rooms (Gabor et al., 2003; Southwell & Wistow 1995; Yinnon et al., 1992). The major advantage of single-bed rooms is reflected in Press Ganey's national satisfaction survey, which obtained data from 2.1 million patients in 1,462 facilities during 2003. Results showed that satisfaction with noise levels was on average 11.2% higher for patients in single-bed rooms than for those in multibed rooms; this pattern held across all patient categories and for different ages, genders, and facility sizes and types (Press Ganey, 2003). This is an extremely large difference, considering that it can be difficult for hospitals to increase satisfaction scores by even two or three percentage points.

Apart from providing single rooms, another approach for quieting facilities and reducing stress is to *eliminate noise sources,* for example, by replacing overhead paging with a noiseless system and insulating pneumatic tubes and ice machines. Also, there is convincing evidence that *installing high-performance sound-absorbing materials* on surfaces such as ceilings, floors, and walls can be effective in reducing noise levels, reverberation or echoing, and sound propagation (Berg, 2001; Blomkvist et al., 2005; Philbin & Gray, 2002).

Provide Nature Distraction to Reduce Stress

Biophilia theory. Wilson's biophilia hypothesis (1984) holds that humans have a partially genetic tendency to respond positively to nature. Ulrich et al. (1993) and Ulrich (2008) have developed theoretical arguments as to why a capability for rapid recovery from stress following challenging episodes was vital for the survival of early humans, and why evolution favored the selection of individuals with this partially genetic proneness for a restorative response to nature. This restoration theory implies that modern humans, as a genetic carryover of evolution, have a capacity to derive stress-reducing responses from certain nature settings and content (e.g., vegetation or water), but have no such disposition toward most built or artifact-dominated environments and materials (e.g., concrete, glass, and metal) (Ulrich, 1993, 1999, 2008). "These theoretical arguments have a practical design implication, which is that designing healthcare buildings with nature features may harness therapeutic influences that are carryovers from evolution, resulting in more restorative and healing patient care settings" (Ulrich, 2008, forthcoming).

Research on restorative effects of nature. Upwards of a score of scientific studies of people in nonhealthcare situations as well as patients in hospitals have generated strong evidence that real or simulated views of nature can produce substantial restoration from stress. The strength of these findings is enhanced by the fact that some studies have used randomized controlled research designs and obtained physiological as well as self-report measurements of stress. Investigators have reported consistently that stress-reducing or restorative benefits of viewing nature are manifested as a constellation of positive emotional, psychological, and physiological changes. Positive feelings such as pleasantness and calm increase, while anxiety, anger, or other negative emotions diminish (Hartig, Book, Garvill, Olsson & Gärling, 1995; Ulrich, 1979; Ulrich, 1991; Van den Berg, Koole, & Van der Wulp, 2003). Also, many nature scenes sustain positive interest and thus function as pleasant distractions that may block worrisome, stressful thoughts (Ulrich, 1981.) Regarding the physiological effects of nature exposure, restoration is apparent when changes in bodily systems indicate decreased stress mobilization (for instance, reduced sympathetic nervous system activity). Physiological restoration is manifested within 3 minutes at most, or as fast as a few seconds in certain systems (Fredrickson & Levenson, 1998; Hartig, Evans, Jamner, Davis & Gärling, 2003; Joye, 2007; Laumann, Gärling, & Stormark, 2003; Parsons & Hartig, 2000; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Ulrich, 1981; Ulrich, Simons, & Miles, 2003). In contrast to viewing nature-dominated settings, there is convincing evidence that looking at built environments that lack nature (e.g., parking lots, roof tops, and rooms) is significantly less effective in fostering restoration and may worsen stress (e.g., Ulrich, 1979, 1991; Van den Berg et al., 2003).

Nature and patient stress. In an interview study of the elderly in long-term care facilities, residents reported a preference for windows with prominent views of nature, but expressed dislike for window views of built content that lacked nature (Kearney & Winterbottom, 2005). Survey research on hospital patients also suggests that they prefer and attribute importance to having a bedside window view of nature (Verderber, 1986).

Furthermore, studies on patients indicate that viewing nature images for only a few minutes can promote significant restoration from stress or anxiety. One well-controlled clinical trial measured restoration from anxiety in patients waiting to undergo dental surgery in a room with or without an aquarium on different days (Katcher, Segal, & Beck, 1984). Findings suggested that anxiety was lower on days when the aquarium was present, and clinicians' ratings for patient compliance during surgery were higher. Heerwagen (1990) studied patients in a dental clinic and found that psychological and physiological markers of stress—including elevated blood pressure and heart rate—were diminished on days when a large nature mural was hung on a wall of the waiting room, in contrast with days when the wall was blank. One strong randomized prospective study of blood donors in a waiting room found that blood pressure and pulse were lower on days when a wall-mounted television displayed a nature videotape, compared to days when continuous daytime television programs or a videotape of urban areas and buildings were aired (Ulrich et al., 2003). A quasi-experimental study of patients with dementia, including Alzheimer's disease, suggested that adding large, color nature images and a nature sound track (birds, brook) to a shower room diminished stress and reduced incidents of aggressive, agitated behavior (Whall et al., 1997).

As mentioned in another section (Reducing Patients' Pain), strong studies have found that exposing patients to nature lessens stress, anxiety, and pain. A prospective clinical trial by Ulrich and colleagues (1993) found that heart-surgery patients in ICUs who were randomly assigned a picture with a landscape scene with trees and water reported less anxiety and stress and needed fewer doses of strong pain drugs than a control group that had been assigned no pictures. In the same study, another group of patients assigned an abstract picture had worse outcomes than the control group. Ulrich (1984) reported that patients recovering from abdominal surgery suffered fewer minor postsurgical complications linked to stress (e.g., headache), had better emotional well-being, required fewer doses of pain drugs, and had shorter hospital stays if they had a bedside window view of nature (trees) rather than a brick wall. Research on burn patients suggested that exposure to a nature videotape during burn dressing changes reduced anxiety, stress, and pain intensity (Miller et al., 1992).

Gardens for reducing stress. A few studies suggest that gardens can be effective restorative settings for stressed patients, families, and staff (Marcus & Barnes, 1999; Sherman, Varni, Ulrich, & Malcarne, 2005; Ulrich, 1999; Whitehouse et al., 2001). Well-designed gardens not only can provide restorative nature views, but they also reduce stress and improve outcomes through other mechanisms, such as fostering access to social support, restorative escape, and control with respect to stressful clinical environments (Ulrich, 1999, 2008). Marcus and Barnes (1995) used behavioral observation and interview methods in postoccupancy studies of four hospital gardens and concluded that recovery from stress was the most important benefit realized by nearly all garden users. Other postoccupancy research likewise has found that patients and families who use hospital gardens report reduced stress and improved emotional well-being (Whitehouse et al., 2001). A quasi-experimental investigation of three gardens in a pediatric cancer center showed that participants (patients, families, staff) reported lower stress levels when in the gardens than inside the hospital (Sherman et al., 2005).

Limited evidence suggests that gardens tend to alleviate stress effectively for adult users when they contain green or verdant foliage, flowers, water, grassy spaces with trees or large shrubs, a modicum of spatial openness, and compatible pleasant nature sounds, such as birds and water (Marcus & Barnes, 1995, 1999; Ulrich, 1999, 2008). Broadly similar findings have emerged from research on gardens and outdoor spaces in assisted living facilities for the elderly. Rodiek (2005) surveyed elderly residents and observed their behavior in 14 assisted living facilities and reported that residents preferred outdoor spaces with greenery, flowers, birds, and water features.

Art in healthcare environments. Rigorous studies on hospital art are sparse, and most have measured patient art preferences rather than effects on outcomes such as pain. The limited findings nonetheless show similarities to results from nature studies. Results suggest a consistent pattern wherein the great majority of patients prefer and respond positively to representational nature art, but many react negatively to abstract art (Carpman & Grant, 1993; Ulrich, 1991; Ulrich & Gilpin, 2003). Nanda, Hathorn, and Neumann (2007) displayed a diverse collection of 17 paintings to patients in their hospital rooms, and asked them to rate each painting for the following questions: (1) How does the picture make you feel, and (2) Would you like to hang this picture in your hospital room? Findings indicated that patients were significantly more positive about nature paintings (landscapes with verdant foliage, flowers, and water) than they were about best-selling pictures or even works by masters such as Chagall and Van Gogh (Nanda et al., 2007). The most positively rated painting depicted a gentle waterfall with vegetation. In the same research, representational nature paintings containing human figures and harmless animals such as deer were preferred over counterparts that were somewhat abstract. Eisen (2006) studied the art preferences of schoolchildren and hospitalized pediatric patients across four age groups: 5–7, 8–10, 11–13, and 14–17 years of age. Findings suggested that, irrespective of age or gender, the great majority of hospitalized pediatric patients and schoolchildren were similar in preferring nature art (such as a forest setting with lake and deer) over abstract or cartoon-like images.

Although nature pictures elicit positive reactions, there is limited evidence that emotionally inappropriate art subject matter or styles can increase stress and worsen other outcomes (Ulrich, 1991, 1999; Ulrich & Gilpin, 2003). It may be unreasonable to expect all art to be suitable for high-stress healthcare spaces, because art varies enormously in subject matter and style, and much art is emotionally challenging or provocative. The pitfalls of displaying emotionally challenging art are revealed by a study of psychiatric patients housed in a unit extensively furnished with a diverse collection of wall-mounted paintings and prints (Ulrich, 1991). Interviews with patients suggested strongly negative reactions to artworks that were ambiguous, surreal, or could be interpreted in multiple ways. The same patients, however, reported having positive feelings and associations with respect to nature artwork. Additional evidence on the stressful impact of abstract art comes from a study of a sculpture installation created for cancer patients in a large university hospital (Ulrich, 1999). Prominent in the installation were several tall metal sculptures dominated by straight-edged and abstract forms, many having pointed or piercing features. A questionnaire study found that 22% of the patients reported having an overall negative emotional response to the sculpture garden (Hefferman, Morstatt, Saltzman & Strunc, 1995). Many found the sculpture ambiguous ("doesn't make any sense"), and some patients interpreted the sculptures as frightening and asked for a room change so they would not overlook the artworks (Ulrich, 1999).

Reducing Depression

Summary of Evidence and Recommendations

Depression is a serious, widespread, and costly problem in healthcare facilities. A large body of rigorous evidence indicates that exposure to bright artificial light and daylight is effective in reducing depression and improving mood, even for people hospitalized with severe depression. Artificial light is commonly used in structured or formal protocols for treating depression. A few retrospective studies suggest that hospitalized adult patients with depression can have more favorable recovery outcomes, including shorter stays, if they are assigned to sunnier rooms rather than rooms that receive less daylight or are always in shade. (See also Reducing Patients' Pain.) The credibility of the limited findings linking greater daylight or sun exposure to improved depression-related outcomes is enhanced by the fact that the many strong studies using bright artificial light have obtained broadly parallel results.

The evidence that patients' depression is diminished by daylight exposure implies the importance of the orientation and site planning of healthcare buildings (Ulrich et al., 2006). Site plans where some buildings block daylight or sun from others should be avoided. Hospitals—and in particular mental health facilities—should be designed and sited to ensure that depressed patients have abundant natural light. Providing larger windows in patient rooms and other spaces might also help alleviate depression by permitting more exposure to daylight. The use of bright artificial light warrants consideration in settings where depression is a problem and sufficient daylight is not available.

Effects of Light on Depression

The mechanisms by which *light treatment* alleviates depression are not fully understood. Light falling on the retina influences the activity of the pineal gland and by this pathway suppresses or delays secretion of melatonin, thereby reducing depression, increasing daytime alertness, and fostering better sleep quality (Martiny, 2004). A meta-analysis of 20 randomized controlled studies published in the *American Journal of Psychiatry* reached the powerful conclusion that light treatment for nonseasonal and seasonal depression is "efficacious, with effect sizes equivalent to those in most antidepressant pharmacotherapy trials" (Golden et al., 2005, p. 656). Additionally, light exposure offers the important advantage of being faster acting than antidepressant drugs. In this regard, several studies suggest that light can produce significant reduction of depression after less than 2 weeks of treatment, while antidepressant drugs require at least 4–6 weeks before effective onset. Some studies suggest that exposure to morning light may be more effective than afternoon or evening light (e.g., Lewy et al., 1998). However, exposure occurring in the middle of the day or afternoon also significantly reduces depression (Martiny, 2004).

Other research focused on *daylight* rather than artificial light. A retrospective study in a Canadian facility found that adult patients hospitalized for severe depression had shorter stays by an average of 2.6 days if they were assigned to sunny rooms rather than rooms that were always in shade (Beauchemin & Hays, 1996). Similarly, a study in an Italian hospital found that patients hospitalized for bipolar depression stayed an average of 3.7 fewer days if they were assigned east-facing rooms exposed to bright morning light, compared to patients in west-facing rooms with less sunlight (Benedetti, Colombo, Barbini, Campori, & Smeraldi, 2001). Depression is a serious problem not only for mental health patients, but also for several other categories of patients, such as those with cardiovascular disease and cancer. An investigation of myocardial infarction patients in an ICU in a Canadian hospital suggested that female patients had shorter stays if their rooms had sunny versus shaded or dim window exposures (Beauchemin & Hays, 1998). In the same study, mortality in both sexes was lower in sunny rooms than in north-facing shaded rooms.

Reducing Length of Stay

Summary of Evidence and Recommendations

There is limited literature that directly links the physical environments of hospitals with patients' length of stay. However, the few studies conducted on light and nature views among specific types of patients have been strong, and they have consistently identified a positive impact from both. Additional studies are needed to confirm these findings and to test them among a broader range of patient types.

Sunlight

As mentioned in the section on Reducing Depression, exposure to sunlight has been reported to affect the length of patients' hospital stays. One research group studied the impact of the amount of natural light on the length of hospitalization of patients with unipolar and bipolar disorder. The researchers found that bipolar patients randomly assigned to the brighter, east-facing rooms (exposed to direct sunlight in the morning) had a 3.67-day shorter mean hospital stay than patients in west-facing rooms (Benedetti et al., 2001). Beauchemin and Hays (1996) analyzed the two-year data of psychiatric unit patients with depression and found that patients in the sunny rooms stayed an average of 2.6 fewer days than those in the sunless rooms. In another study, the researchers examined the length of stay and mortality rate of 628 myocardial infarction patients who had been randomly assigned to sunny and dull rooms. Patients in sunny rooms had shorter lengths of stay than patients in dull rooms, with a more significant difference for women patients (2.3 days in sunny rooms versus 3.3 days in dull rooms) (Beauchemin & Hays, 1998). The rate of mortality in sunny rooms was also lower than in the dull rooms (21/293 sunny versus 39/335 dull). A retrospective study of *climate* and patient data documented a correlation between climate variables and the average length of stay of psychiatric inpatients in Veterans Health Administration hospitals nationwide (Federman, Drebing, Boisvert, & Penk, 2000). Medical centers located in warmer and drier climates had shorter lengths of stay, and those in colder climates had the longest lengths of stay in winter and fall.

Views of Nature

As discussed previously, various studies have demonstrated the beneficial impact of exposure to nature views (real nature or simulated nature, such as pictures, videos, or virtual reality) in improving patient outcomes such as stress, pain, and length of stay (e.g., Diette et al., 2003; Tse et al., 2002; Ulrich, 1984, 1991). One strong study reported the relationship between exposure to nature views and length of stay, where patients recovering from abdominal surgery had a shorter stay if they had a bedside window view of nature rather than looking out onto a brick wall (Ulrich, 1984). More research is needed to examine the impact of visual exposure to nature on the overall healing process and length of stay.

Comprehensive Programs

In reality, changes in procedural or programmatic activities to improve healthcare often were accompanied by design modifications. In such cases, it is difficult to disentangle the independent effect of design interventions. For example, Good Samaritan Hospital in Cincinnati, Ohio, conducted a study in its NICU for 1 year before and 1 year after an intervention, which consisted of a major renovation and the implementation of a comprehensive developmental care program that included training and other activities (Altimier, Eichel, Warner, Tedeschi, & Brown, 2005). The design modifications focused on improving lighting and acoustics, increasing square footage per infant bed, and addressing family and staff needs (e.g., increased privacy). The sample included 852 infants—419 preintervention and 433 postintervention—grouped into three categories based on gestation (24–27 weeks, 28–30 weeks, and 31–34 weeks). The preintervention infants had lengths of stay of 79, 58, and 34 days, respectively, as compared to 58, 45, and 23 days for infants postintervention. Other health-related benefits from the environmental and programmatic changes also were observed.

Furthermore, in the section of this article called Reducing Hospital-Acquired Infections, a large body of literature indicated that the design of the physical environment strongly influences infection rates by affecting the airborne, contact, and waterborne transmission of infections. In this respect, EBD measures, by reducing nosocomial infection rates, play a key role in shortening hospital stays.

Reducing Spatial Disorientation

Summary of Evidence and Recommendations

Wayfinding problems in hospitals are costly and stressful and have a particular impact on outpatients and visitors, who are often unfamiliar with the hospital and are otherwise stressed and disoriented. In a study conducted at a major regional 604-bed tertiary-care hospital, the annual cost of the wayfinding system was calculated to be more than $220,000 per year in the main hospital, or $448 per bed per year in 1990. Much of this was the hidden cost of direction-giving by people other than information staff, which occupied more than 4,500 staff hours, the equivalent of more than two full-time positions (Zimring, 1990). Several other studies have also documented the high cost of wayfinding problems in hospitals (Carpman, Grant, & Simmons, 1990; Christensen, 1979; Foxall & Hackett, 1994).

A large body of literature has explored how people find their way through hospitals and other complex buildings. For example, Peponis, Zimring, and Choi (1990) found that people tend to have predictable paths when they explore and find their way in hospitals. However, space syntax analysis shows that these are often not the most direct paths or the routes that are designated as the “main paths,” but rather the routes that are the most accessible to all of the other paths in the hospital. Not surprisingly, more complex overall layouts are more difficult to find one’s way in (Arthur & Passini, 1992; Drinkard, 1984; O’Neill, 1992; O’Neill, 1991a, 1991b; Ortega-Andeane & Urbina-Soria, 1988). Several studies have found that characteristics such as turns other than right turns are harder to maintain (Carpman & Grant, 1993).

Whereas there is growing evidence about how people find their way, there is relatively little research that directly assesses the comparative performance of different wayfinding systems or the impact of wayfinding on other healthcare outcomes. Limited evidence shows that wayfinding problems cannot be tackled piecemeal. A wayfinding system, as the name implies, is not just about better signage or colored lines on floors. Rather, hospitals should provide integrated systems that include coordinated elements, such as visible and easy-to-understand signs and numbers; clear and consistent verbal directions; consistent and clear paper, mail-out, and electronic information; and a legible physical setting (Carpman & Grant, 1993). A well-integrated wayfinding system includes four main components that work at different levels: (1) administrative and procedural levels, (2) external building cues, (3) local information, and (4) global structure.

Administrative and Procedural Information

Certain organizational strategies can provide key information to patients and help them prepare for their hospital visit. Examples include mail-out maps, electronic information available on the Web or at kiosks, and verbal directions. These issues are not dealt with in this review because they are not directly related to the design of hospital physical environments.

External Building Cues

Signs and cues that lead to the hospital, especially to the parking lot, must be considered carefully because they are the patient's first point of contact with the hospital. For example, Carpman, Grant, and Simmons (1985) conducted a video simulation study to assess the relative role of signs and seeing a destination. The hospital wanted to direct most traffic to a parking structure rather than to a drop-off lane. When the researchers showed prospective visitors a simulated video with a design alternative that allowed arriving drivers to see the main pavilion with the drop-off lane, 37% of the respondents said that they would turn into the drop circle when they could see the entry to the garage, ignoring the signs. Consequently, the hospital chose to redesign the entry.

Local Information

Once patients find their way to the building from the parking lot, they are faced with the prospect of identifying their destination. Informational handouts, information desks, you-are-here maps, directories, and signage along the way are critical wayfinding aids (Carpman, Grant, & Simmons, 1983; Levine, Marchon, & Hanley, 1984; Nelson-Shulman, 1983-84; Wright, Hull, & Lickorish, 1993). In an experimental study, researchers found that patients who had the benefit of an information system (including welcome sign, hospital information booklet, patient letter, and orientation aids) upon reaching the admitting area were more self-reliant and made fewer demands on staff. In contrast, uninformed patients rated the hospital less favorably and had elevated heart rates (Nelson-Shulman, 1983-84). Information provided in you-are-here maps can be useful. However, you-are-here maps should be well oriented so that the top signifies the direction of movement for ease of use. When the maps were aligned in directions other than the forward position, people not only took much longer to find their destination, but their efforts were significantly less accurate (Levine et al., 1984). Another study found that people who used signs found their destination faster than those who used only maps (Butler, Acquino, Hissong, & Scott, 1993). However, people who were given a combination of handheld maps and wall signs reached their destination more often than those who used only wall signs (Wright et al., 1993).

It is critical to design signage systems with logical room numbering and comprehensible nomenclature for departments (Carpman & Grant, 1993; Carpman, Grant, & Simmons, 1984). For example, inpatients, outpatients, and visitors to a hospital preferred simple terms such as *walkway* or *general hospital* over more complex or less familiar terms such as *overhead link, medical pavilion,* or *health-sciences complex.*

Contrary to the belief that fewer signs in hospital hallways means less clutter and hence less confusion, an experimental study found that patients who had access to more signs along the way were faster, less hesitant, asked for directions fewer times, and reported lower levels of stress (Carpman et al., 1984). Based on this study, the authors suggest that directional signs be placed at or before every major intersection, at major destinations, and where a single environmental cue or a series of such cues (e.g., changes in flooring material) convey the message that the individual is moving from one area into another. If there are no key decision points along a route, signs should be placed approximately every 150 to 250 feet.

Global Structure

In addition to local properties of the spaces that people move through, there are specific characteristics of the overall structure of the system of rooms and corridors that affect the paths people take (Haq & Zimring, 2003; Peponis et al., 1990). Based on observations of participants' search patterns and objective measures of spatial characteristics, researchers found that participants tended to move along more "integrated" routes—routes that are, on average, more accessible from a greater number of spaces because there are fewer turns from all other routes in the hospital. This research suggests that it may be important to identify such integrated routes in the plan when situating important facilities and key points such as the entrance (Peponis et al., 1990). In support of these findings, Baskaya, Wilson, and Ozcan (2004) found that people got lost less frequently in a hospital where the entrance is next to the main hallway than in a hospital where the entrance is not next to the main hallway. One limitation of the study, however, is that the hospitals compared in this case study were quite different; the hospital with better wayfinding systems also had an asymmetrical layout and outside views that the comparison hospital did not have, which might also have contributed to the improved wayfinding.

Some studies at the global scale have looked at properties of building layout that facilitate or impede movement. For example, when 56 study participants were given the wayfinding task of locating five targets in four synthetic office floor plans that were modeled on an actual floor plan, virtual environments with perpendicular intersecting hallways had better wayfinding performance than those with angled intersections (Werner & Schindler, 2004). Another study supports this finding by a design experiment that compared perpendicular and angled intersections. The study had the same 12 participants for both types of intersections in synthetic floor plans (Ruddle & Peruch, 2004).

The research supports the value of a systems approach to wayfinding, and it is not sufficient to consider one or two components separately. Well-designed signs are likely to be quite ineffective in a building that is highly complicated and does not provide simple cues that enable natural movement. For example, some hospitals with existing complex buildings tend to simply superimpose a signage system to try to make things work. This strategy is ineffective in most cases. On the other hand, while there are more than 18 studies that look at wayfinding in hospitals and other buildings (Baskaya et al., 2004; Brown, Wright, & Brown, 1997; Butler et al., 1993; Carpman & Grant, 1993; Carpman et al., 1983, 1984; Grover, 1971; Haq & Zimring, 2003; Levine et al., 1984; Nelson-Shulman, 1983-84; Ortega-Andeane, & Urbina-Soria, 1988; Passini, Rainville, Marchand, & Joanette, 1995; Peponis et al., 1990; Schneider & Taylor, 1999; Weisman, 1981; Wright et al., 1993; Zimring, 1990), it is quite difficult to isolate the independent role of a single design factor on wayfinding performance or visitors' stress.

It is essential that these different pieces of information come together while designing new hospitals, when there is an opportunity to develop an effective wayfinding system at multiple levels. Additional studies are needed to ascertain the magnitude of stress that wayfinding problems may create for outpatients and family members.

Improving Patient Privacy and Confidentiality

Summary of Evidence and Recommendations

The protection of patient confidentiality and privacy has been written into U.S. law through the Health Insurance Portability and Accountability Act (HIPAA). Research has shown that inadequate privacy may lower patient satisfaction and can worsen healthcare outcomes if patients withhold personal information or refuse to be examined because of privacy concerns (Barlas, Sama, Ward, & Lesser, 2001). *Speech privacy* is one important issue addressed by HIPAA, including how well a private conversation can be overheard by an unintended listener. The *AIA/AHA Draft Interim Sound and Vibration Design Guidelines for Hospital and Healthcare Facilities* were developed in 2006, and they will be revised and enforced in professional practice (ANSI S12/WG44 [Healthcare Acoustics and Speech Privacy] and the Joint ASA/INCE/NCAC Subcommittee on Healthcare Acoustics & Speech Privacy; Skyes, 2006).

Despite the growing importance of speech privacy in healthcare settings, existing research in this area is sparse. We identified nine pertinent empirical studies that provide some evidence-based guidance regarding what designers can do to protect the privacy of patient speech. Extensive national survey data support the provision of single-bed rooms to increase patient privacy and confidentiality (Press Ganey, 2003). When single rooms are not available, as in many EDs, installing hard-wall partitions to provide speech privacy is preferable to curtains (Barlas et al., 2001; Karro, Dent, & Farish, 2005; Mlinek & Pierce, 1997). To prevent sound leakage and privacy breaches through the ceiling, hard-wall partitions should extend to the support ceiling or deck instead of stopping at the ceiling plane. Installing high-performance sound-absorbing ceiling tiles can shorten reverberation times, improve speech intelligibility, diminish propagation of voices and sounds, and lessen sound pressure intensity (Hagerman et al., 2005; Philbin & Gray, 2002). Furthermore, providing private discussion rooms near waiting, admission, and reception areas may help prevent breaches of speech privacy (Joseph & Ulrich, 2007).

Locations and Rates of Speech Privacy Incidents

Speech privacy in EDs. The ED is the most studied setting within healthcare facilities with respect to speech privacy. EDs are subject to frequent privacy breaches due to high volumes of patients and staff, the severity of patients' diseases or injuries, numerous conversations involving confidential patient information, and the widespread practice of placing patients in multibed rooms with curtain partitions. Mlinek and Pierce's (1997) observational study in EDs found that 100% of healthcare staff committed breaches of speech privacy. Karro and colleagues (2005) reported a rate of 45% for visual and auditory privacy breaches in EDs. Additionally, studies have examined specific locations within EDs for rates of privacy incidents. For triage/waiting areas, Mlinek and Pierce (1997) observed a rate of 53% for speech privacy breaches, and Karro et al. (2005) found a self-reported rate of 55% for both speech and visual privacy incidents. For all ED cubicle areas, Karro et al. (2005) reported a rate of 62% for speech and visual privacy breaches, and Olsen & Sabin (2003) found that 36% of patients overheard conversations. Rooms located closest to physician and nurse work areas typically had the highest rates of confidentiality breaches (Karro et al., 2005).

Speech privacy in patient rooms. No rigorous study was identified that directly observed the occurrence of speech privacy violations within patient rooms in general wards or ICUs. However, extensive survey data have shown that single-bed rooms, compared to multibed rooms, provide better protection for patient speech privacy (Press Ganey, 2003).

Environmental Approaches to Protect Speech Privacy

Speech privacy research in healthcare settings is at an early stage of development. The limited evidence suggests that some design measures can enhance speech privacy, including the use of hard-wall space partitions, single-bed rooms, high-performance sound-absorbing materials, and private discussion rooms or spaces.

Space partitions in EDs. The comparison between hard-wall and curtain partitions, especially in EDs, is the most studied architectural issue in this area (Barlas et al., 2001; Karro et al., 2005; Mlinek & Pierce, 1997; Olsen & Sabin, 2003). As might be expected, hard-wall partitions provide substantially better protection for speech privacy than curtains. Karro et al.'s survey study of EDs reported the rate for both visual and auditory privacy breaches to be 45% in areas with curtain partitions, but only 13% in hard-walled rooms. Mlinek & Pierce's (1997) direct observation research found the rate of speech privacy incidents (i.e., conversations being overheard from the next room) to be 100% for bed spaces with curtain partitions or even single-pane glass partitions, but 0% for rooms with solid walls and doors. It is noteworthy that these two studies arrived at different results, probably because of different measurement methods. In addition, an earlier study (Barlas et al., 2001) that used the same survey instrument as Karro et al. (2005) also found a much lower rate of privacy incidents in hard-walled cubicles than curtained cubicles. Different findings emerged from Olsen and Sabin's (2003) self-report surveys, where adult patients and parents of pediatric patients reported no significant differences in the overall rates of patients or parents overhearing conversations between curtained rooms and walled rooms with open doors or curtained entrances. However, the locations of overheard conversations were quite different; in hard-walled rooms, participants overheard fewer conversations from adjacent rooms or bed spaces than curtained spaces (15% versus 55%), but more conversations from hallways or nursing stations. A possible explanation is the tunneling effect of the particular hallway design and the use of open doors or curtained entrances instead of solid, closed doors.

Single-bed patient rooms. For patient rooms, it is reasonable to expect that single rooms help to protect speech privacy because fewer unintended listeners (e.g., patients and healthcare staff) are present compared with multibed rooms. Press Ganey's national data (2003) showed that patients in single-bed rooms were consistently much more satisfied with their privacy (4.5% higher) than patients in double rooms, across all major patient categories and types of units, and across different age and gender groups. Although speech privacy was not directly measured in this survey, it likely played a role in the overall sense of privacy. Other research has found that nurses perceive single-bed rooms to be more appropriate for patient examinations and collection of patient histories (Chaudhury et al., 2006). Enhanced confidentiality and privacy were among the important reasons for such evaluations.

High-performance sound-absorbing materials for environmental surfaces. As previously mentioned (in Reducing Patients' Sleep and Reducing Patient Stress), materials for surfaces such as ceilings, floors, and walls substantially affect acoustic conditions. Existing studies have demonstrated the positive effects of installing high-performance ceiling tiles and other sound-absorbing surface materials in reducing reverberation time, sound propagation, and noise pressure levels (Hagerman et al., 2005; Philbin & Gray, 2002). Such design measures also would likely enhance the speech privacy of environments, because the improved acoustic conditions, such as reduced sound propagation, would lessen voice travel to adjoining spaces.

Other environmental approaches to protect speech privacy. Certain other environmental approaches may also be helpful. As pointed out by Joseph and Ulrich (2007), *providing private discussion rooms* should help reduce privacy breaches in spaces such as waiting areas and admission and reception areas, where confidential information often is discussed. Such rooms are also necessary for patient floors with multibed rooms to protect speech privacy during communication between physicians and patients or their families. Additionally, the use of a *wireless communication system* may be considered so that healthcare staff, patients, and their families need not raise their voices to be heard across large spaces or down hallways. In addition, to protect speech privacy some ceiling system manufacturers recommended the use of *sound masking,* which is "the precise application of electronic background sound that blends into the environment to cover up or mask unwanted noise" (Armstrong Ceiling System, 2003). However, there appears to be a lack of solid research supporting its appropriateness and safety in healthcare settings, because sound masking in some situations might lower clinicians' ability to detect and respond to many different types of sounds, ranging from alarms to the spoken communication of staff (Joseph & Ulrich, 2007).

Directions for future research. Although the limited amount of research discussed here provides some important evidence, there is a need for future studies that use more sensitive and advanced acoustic measures, such as the privacy index (PI). PI takes into account the acoustic performance of all finishes in a space, including ceilings, floors, and furniture (Armstrong Ceiling System, 2003), and it was employed by the new *Interim Sound and Vibration Design Guidelines for Hospital and Healthcare Facilities* (ANSI S12/WG44 [Health-care Acoustics and Speech Privacy] and the Joint ASA/INCE/NCAC Subcommittee on Healthcare Acoustics & Speech Privacy). It is important that both researchers and designers keep informed regarding these updated standards.

Improving Communication with Patients and Family Members

Summary of Evidence and Recommendations

The communication among patients, family, and staff is important because it can provide social support to patients and family members, facilitate family members' involvement in patient care, and also increase patient satisfaction with care (Laitinen & Isola, 1996; Press Ganey, 2007). Several studies have demonstrated that providing *single-patient rooms* and *private discussion areas* can facilitate communication (Astedt-Kurki, Paavilainen, Tammentie, & Paunonen-Ilmonen, 2001; Kaldenburg, 1999). Limited evidence supports the use of dim lighting instead of bright lighting in counseling rooms to achieve better communication and counseling results (Miwa & Hanyu, 2006). More research is needed to explore further environment-communication relationships in more diverse healthcare settings and how design measures can enhance communication.

Importance of Communication

Evidence has shown that staff-family communication can provide social support to patients, their family members, and staff, and facilitate family members' involvement in patient care. A survey comprising 369 relatives and significant others of elderly patients indicated that family-staff communication is a good source of social support for families: it helps meet family needs and reduces patient and family anxiety (Laitinen & Isola, 1996). The same study also found that better family-staff communication increased the level of family members' involvement in providing care. In fact, the lack of communication between family members and staff was the primary reason cited for family members' failure to be involved in the care of patients.

Good communication is also of the utmost importance in terms of patient satisfaction with care across different patient categories (Press Ganey, 2007). According to the data obtained from 2,359,935 patients nationally in 2006, the five top-priority issues that patients identified as affecting satisfaction are associated with communication and empathy, including (1) response to concerns/complaints made during the hospital stay; (2) staff sensitivity to the inconvenience that health problems and hospitalization can cause;

(3) staff effort to include you in decision making about your treatment; (4) degree to which hospital staff addressed your emotional needs; and (5) how well the nurses kept you informed. These five priorities also represent specific needs of family members, such as information, assurance, proximity, support, and comfort, which were identified by several other studies (Engli & Kirsivali-Farmer, 1993; Mathis, 1984; Molter, 1979; Verhaeghe, Defloor, Van Zuuren, Duijnstee, & Grypdonck, 2005).

Environmental Factors Affecting Communication

Several studies have found that the degree of interaction and communication in healthcare settings depends on nurses' and family members' personal characteristics, as well as how the staff-family relationship has been built (Astedt-Kurki et al., 2001; Hupcey, 1998; Soderstrom, Saveman, & Benzein, 2006; Soderstrom, Benzein, & Saveman, 2003).

Providing single-patient rooms and private areas has the benefit of facilitating communication, along with other important advantages such as preventing infections, better privacy, and less noise and crowding for families. A study by Astedt-Kurki et al. (2001) identified several factors facilitating or complicating the interaction between an adult patient's family members and nursing staff. Using a questionnaire, data were collected from 155 nursing staff working on the wards and outpatient departments at a university hospital in Sweden. Interestingly enough, one of the factors complicating interaction was the absence of a peaceful place for discussion, along with the staff's haste, shift-work, and family members' shyness of approaching the staff. Semiprivate patient rooms are perceived as busy places where roommates and their families can overhear discussions. This study implies that spaces that are private and peaceful may contribute to improved communication. Kaldenburg (1999) has found that staff members in multibed rooms are reluctant to discuss patient issues or give information when they are within hearing distance of a roommate, out of respect for patient privacy. National survey data also show that patients consistently report significantly higher satisfaction with communication from nurses and physicians when they are in single rooms compared to when they have one or more roommates (Press Ganey, 2003).

It is unfortunate that there is not much research on how the built environment enhances or hinders communication, other than for single- versus multibed rooms. There is one study that examined the effect of a specific environmental factor—dim lighting—on enhancing communication (Miwa & Hanyu, 2006). Using 80 undergraduate students as subjects, this experimental study compared four different interior conditions of counseling rooms by using different decorations (with or without home-like decorations) and types of lighting (bright or dim). The researchers found that participants in the dim lighting conditions spoke longer about themselves and their identity during the interview than did participants in the bright lighting conditions, which meant more self-disclosure, more pleasant and relaxed feelings, and more favorable impressions of the interviewer. However, they found the decorations had no significant effect. Thus, this study suggested that dim lighting in counseling rooms could enhance communication.

Fostering Social Support

Summary of Evidence and Recommendations

Social support has been described as emotional, informational, and tangible support (Kahn & Antonucci, 1980), and is normally received from people in a social network and the family (McMurray, 1998). However, contacts with one's social support network are limited while the patient is hospitalized (Koivula, Tarkka, Tarkka, Laippala, & Paunonen-Ilmonen, 2002). This is unfortunate because the need for social support increases when an individual experiences changes such as an unexpected situation or stressful event (Tarkka, Paavilainen, Lehti, & Astedt-Kurki, 2003), including a hospitalization. There is strong evidence showing the benefits of social support for patients and their families (Kaunonen, Tarkka, Paunonen, & Laippala, 1999; Koivula, Paunonen-Ilmonen, Tarkka, Tarkka, & Laippala, 2002; Koivula, Tarkka et al., 2002; McMurray, 1998; Tarkka et al., 2003).

However, there is only a moderate level of evidence linking design features to the level or quality of social support. Some studies have shown that *single-patient rooms* increase the presence of family members and social support, as compared with multibed rooms (Chaudhury, Mahmood, & Valente, 2003; Sallstrom, Sandman, & Norberg, 1987). There is also evidence that recommends the provision of *lounges, day rooms, and waiting rooms with comfortable, movable furniture arranged in small, flexible groupings,* in order to facilitate social interactions (Holahan, 1972; Melin & Gotestam, 1981; Peterson, Knapp, & Rosen, 1977; Sommer & Ross, 1958). The use of carpeting instead of vinyl for floors in patient rooms appeared to increase the length of family's stay (Harris, 2000). But such measures should be applied with a comprehensive consideration, including the possible impact on infection control and cleaning, which is an area that awaits more research. (See Reducing Hospital-Acquired Infections.)

Social Support for Patients

Several studies have found that social support from nurses, families, and significant others reduces patient stress, improves patients' physiological outcomes, and has a positive influence on both patients and family members (Kaunonen et al., 1999; Koivula, Tarkka et al., 2002; McMurray, 1998; Tarkka et al., 2003). Researchers in Finland examined the impact of in-hospital social support on coronary artery bypass grafting patients' preoperative fear and anxiety, using the survey data collected from 193 inpatients (Koivula, Paunonen-Ilmonen, Tarkka, Tarkka, & Laippala, 2002). They found that when the amount of social support was high, patients experienced lower levels of fear and anxiety.

Several studies also found that increased patient-family interactions, as part of social support from families, improve patients' physiological outcomes and facilitate patient progress (Bay, Kupferschmidt, Opperwall, & Speer, 1988; Chatham, 1978; Happ et al., 2007). An experimental study by Chatham (1978) looked at the impact of social support through patient-family interaction on a patient's postoperative behaviors. An 11-item "Behavioral Checklist" was used to measure manifestations of postcardiotomy psychosis, such as the disorientation, alertness, inappropriateness, confusion, sleep, and anxiety of open-heart surgery patients. Results showed that patients with specific social interactions with families (such as eye contact, frequent touch, and verbal orientation to time, person, and place) exhibited fewer manifestations of postcardiotomy psychosis.

The studies by Hendrickson (1987) and Bruya (1981) showed a decrease in intracranial pressure during family presence and patient-family interactions among patients at risk for increased intracranial pressure. A qualitative study by Happ et al. (2007) also found that family presence and their social support through touching, talking, and surveillance helped patients to deal with their treatments better and facilitated their clinical progress. The study showed that ICU and stepdown patients with family members present withdrew significantly more quickly from long-term mechanical ventilation.

Support for Family Members

There is an extensive body of literature emphasizing the need for the social support of patients' families. The evidence indicates that social support reduces families' stress, anxiety, and depression, and increases their satisfaction with the hospital stay. A family member's long-term illness affects the well-being and health of the entire family. Family members also need support to cope with a long-term illness or the death of their loved one (Tarkka et al., 2003). For example, a questionnaire study of 318 Finnish widows and widowers found that social support helped in coping with grief (Kaunonen et al., 1999). The results showed that the study subjects receive social support most often from their own families and friends and that they perceived support to be helpful. Respondents who had social support were able to grieve by expressing their feelings and forgetting the demands of normal life, whereas those without support had to hold themselves up and continue the duties of normal life, which could produce excessive psychological demands without adequate sources for coping. Based on data collected through subject interviews and questionnaires, a study of 417 patient-spouse pairs found that spouse anxiety and depression were correlated with patient psychosocial distress (Moser & Dracup, 2004). They found that patients' psychosocial adjustment to illness was worse when spouses were more anxious or depressed than the patients.

Role of the Physical Environment in Encouraging Social Support

Despite the well-established importance of social support, there is only a moderate amount of research concerning how hospital design can facilitate or hinder access to social support. There is strong evidence that levels of social interaction, and presumably beneficial social support as well, can be increased by providing *lounges, day rooms, and waiting rooms with comfortable, movable furniture arranged in small, flexible groupings*. A few well-designed studies in psychiatric wards and nursing homes have found that the appropriate arrangement of movable seating in dining areas enhances social interaction and also improves eating behaviors, as indicated by the increased food consumption of geriatric patients (Melin & Gotestam, 1981; Peterson et al., 1977). Much research on dayrooms and waiting areas has shown that the widespread practice of arranging seating side-by-side along room walls inhibits social interaction (Holahan, 1972; Sommer & Ross, 1958). A novel study by Harris (2000) found that family and friends stayed substantially longer during visits to rehabilitation patients when patient rooms were carpeted rather than covered with vinyl flooring.

Much evidence indicates that *single-bed rooms* are markedly better than multibed rooms for supporting or accommodating the presence of family and friends. A clear advantage of single-bed rooms in fostering social support stems from the fact that they provide more space and furniture than double rooms to accommodate family presence (Chaudhury et al., 2003). Some research suggests that open-plan multibed rooms deter family presence and therefore reduce social support (Sallstrom et al., 1987). One reason is that multibed rooms greatly reduce privacy for patient-family interactions compared to single rooms, and they are much more likely to have restricted visiting hours. A survey of staff in four hospitals, each of which had a mix of single and double rooms, found that nurses assigned higher ratings to single rooms for accommodating family members (Chaudhury et al., 2003).

Increasing Patient Satisfaction

Summary of Evidence and Recommendations

Environmental satisfaction is a significant predictor of overall satisfaction in healthcare settings (Harris, McBride, Ross, & Curtis, 2002). There is strong evidence that a satisfying environment should be designed with patients' and families' needs in mind. It should provide a comfortable and aesthetically pleasing environment (through the use of color, artwork, etc.), and provide nice window views (preferably with nature), adequate lighting or sunlight, and a helpful information guide. The provision of single-patient rooms can afford favorable environmental features, such as quiet, privacy, an accessible bathroom, and a sense of control, and thereby can improve patients' satisfaction with the healthcare experience.

Evidence From Intervention Studies and Surveys

Telephone interviews with 380 discharged inpatients have helped determine that environmental satisfaction was a significant predictor of overall satisfaction with healthcare, ranking only below perceived quality of nursing and clinical care (Harris et al., 2002). The same study also identified specific environmental factors that were perceived to be pleasing and satisfactory to patients, including: (1) color of the wall, artwork, comfortable bed, television working properly, and easy access to anything in the patient room; (2) a window with a nice view, an accessible bathroom in the room, and a room located away from noisier areas of unit; (3) adequate lighting, quiet surroundings, and a comfortable temperature; (4) a private room, environmental means for privacy (e.g., a closed door); and (5) cleanliness of the room.

Data obtained nationally by Press Ganey (2007) support the importance of and need for better room environments to improve patient satisfaction with the hospital experience. Data show that patients complained about temperatures ("too cold") and high noise levels ("so noisy") in their rooms. Another study by Hagerman et al. (2005) also found a relationship between the noise level in patient rooms and patient satisfaction by comparing patients' responses during the bad acoustic period (with sound-reflecting ceiling tiles) to those in the good acoustic period (with sound-absorbing ceiling tiles). They found that patients treated during the good acoustic period considered staff attitude to be much better, implying that good room acoustics has an effect on patient satisfaction with staff.

There is strong evidence that design changes that make the environment more comfortable, aesthetically pleasing, and informative relieve patient stress and increase satisfaction with the quality of care. Renovating a traditional waiting area in a neurology clinic (e.g., making small changes to the general layout, color scheme, furniture, floor covering, curtains, and providing informational material and information displays) resulted in more positive environmental appraisals, an improved mood, an altered physiological state, and greater reported satisfaction among waiting patients (Leather, Beale, Santos, Watts, & Lee, 2003). Patients in well-decorated and well-appointed, hotel-like rooms rated their attending physicians, housekeeping, food-service staff, food, and the hospital higher than patients in standard rooms (with typical hospital beds, inexpensive family sitting chairs, and no artwork) in the same hospital. Also, they had stronger intentions to use the hospital again and would recommend the hospital to others (Swan, Richardson, & Hutton, 2003).

It is also important to consider how the physical environment can help family members meet their needs to increase their satisfaction with hospital stays. There is a considerable body of literature identifying the needs of family members, especially in the intensive care setting (Engli & Kirsivali-Farmer, 1993; Mathis, 1984; Molter, 1979; Verhaeghe et al., 2005). Molter (1979) investigated and developed the most commonly used instrument for measuring family needs in the ICU—the Critical Care Family Needs Inventory (CCFNI). Among 45 family need statements in CCFNI, there are eight family needs that can be addressed by means of the physical environment: (1) have a waiting room near the patient; (2) see the patient frequently; (3) have a bathroom near the waiting room; (4) have comfortable furniture in the waiting room; (5) have friends nearby for support; (6) have a telephone near the waiting room; (7) have a place to be alone while in the hospital; and (8) provide the ability to be alone at any time. Another study also indicated that having a place to rest, having a waiting area, and offering overnight accommodations were essential for families' satisfaction in the neonatal intensive care setting (Conner & Nelson, 1999).

The previous studies agree in predicting that single-patient rooms could significantly improve patients' and family members' satisfaction with the healthcare experience, because they can accommodate many preferred environmental features such as quiet, privacy, an accessible bathroom, and a sense of control. Several studies have focused on the impact of specific types of single-patient rooms on patient satisfaction and other clinical and financial measures (Brown & Gallant, 2006; Hendrich et al., 2004). Hendrich et al. (2004) conducted a pre/post comparison of the two years before the move to acuity-adaptable, single-patient rooms and three years after the move; they found improvements in predictive indicators of patient satisfaction. Patients were less nervous or withdrawn and treated with more respect, and nurses were regarded as more caring. There was also an improvement in quality and operational cost.

RESULT III: IMPROVING STAFF OUTCOMES THROUGH ENVIRONMENTAL MEASURES

Decreasing Staff Injuries

Summary of Evidence and Recommendations

Hospital workers experience a high rate of occupational injury, especially musculoskeletal injuries attributable to patient handling. Some injuries take healthcare workers away from their normal job duties. It is estimated that up to 38% of all nurses in the United States suffer from back injuries (American Nurses Association, 2002). Based on 2005 data, the rate of occupational injuries and illnesses for hospitals is almost double the rate for all of private industry (8.1 cases per 100 full-time workers versus 4.6 cases per 100 in industry) (Bureau of Labor Statistics, 2007). Further, as a result of these injuries, hospital workers were away from work or on restricted job duties for 3.3 days per year per 100 full-time workers.

Many studies have been undertaken to evaluate the physical stress and strain caused by patient handling. *Ceiling lifts* have been identified the most consistently as reducing the incidence of injury and the cost of injury claims. The research findings have not been as clear regarding the use of ceiling lifts for *repositioning patients,* which, because of the awkward angles required to perform this task, results in greater numbers of injuries; these injuries are not reduced as dramatically by the use of lifts. As with all physical environment interventions, to be most effective it is critical that the introduction of lifts be accompanied by a comprehensive patient lifting program. In fact, most of the studies reviewed involved a combination of lifts and cultural change; therefore it is difficult to isolate the effect of the lifts alone.

Lifts

Musculoskeletal injuries are often caused or aggravated by patient handling. However, it is encouraging that many studies have documented reductions in staff back injuries following the installation of assistive devices and improved procedures or room design (Chhokar et al., 2005; Engst, Chhokar, Miller, Tate, & Yassi, 2005; Evanoff, Wolf, Aton, Canos, & Collins, 2003; Garg & Owen, 1992; Hignett & Evans, 2006; Keir & MacDonell, 2003; Li, Wolf, & Evanoff, 2004; Miller, Engst, Tate, & Yassi, 2006; Yassi et al., 2001). For example, using ceiling-mounted or mobile lifts may help to reduce back injuries. Several studies have found that ceiling lifts were more effective at reducing injuries and require less time and space to use, compared with mobile lifts (Hignett & Evans, 2006; Keir & MacDonell, 2003). A study comparing two long-term care facilities in Canada identified a dramatic difference in the cost of nursing injury claims for the facility that installed ceiling lifts versus the facility that had only mechanical floor lifts. For the year following the installation of the ceiling lifts, this facility experienced a 70% decrease in claims costs and 18 fewer days lost compared to the prior year. In contrast, the facility without the ceiling lifts experienced a 241% increase in claims costs and had 499 additional days lost during the same year compared with the previous year (Miller et al., 2006). Similarly, Engst et al.'s (2005) prospective study found that the unit with ceiling lifts reduced compensation costs for injuries from lifting and transferring patients by 68%, while the control unit without ceiling lifts saw a rise in cost of 68%.

Not surprisingly, lifts are more useful in facilities that require nurses to perform more patient handling activities, such as long-term care facilities. In a comparison of the effect of lifts in acute-care settings versus long-term care facilities, the use of lifts was more frequent in long-term care facilities, which consequently showed greater reductions in lost staff time due to injury (Evanoff et al., 2003). Even when the upfront cost of the lifts is considered, the savings have been demonstrated to be worthwhile. Two separate studies of ceiling lifts revealed a payback of the initial cost in 2.5 years or less (Chhokar et al., 2005; Joseph & Fritz, 2006).

Repositioning

Although overall injury rates are generally found to decline with the introduction of lifts, there have been less consistent findings about the value of lifts when used for repositioning patients rather than lifting them. Two articles reported findings from a study conducted at an extended care unit of a British Columbia hospital that installed 65 ceiling lifts to support 125 beds and three tubs in 1998. The first article examined data from the 20-month period following the installation of the lifts (Ronald et al., 2002). Although there was no overall decrease in musculoskeletal injuries, there was a reduction in the rate of workforce injuries caused by lifting and transferring patients from 14.5 injuries per 100,000 hours worked preintervention to 8.1 injuries per 100,000 hours worked postintervention. A subsequent article looked at data over a three-year period and found a reduction in the overall number of claims and a decrease in the number of injuries from repositioning (Chhokar et al., 2005). Overall claims from patient handling went from 65 during the three years preintervention to 47 postintervention. The difference in repositioning injuries is explained by the fact that there were no repositioning slings available during the first year. Chhokar and colleagues further suggested that the actual reduction in injuries might be greater because back injuries can result from cumulative rather than acute stress, and therefore, some of the injuries reported in the first year after the intervention might be the result of lifting tasks from prior years. In contrast, another study in a 75-bed extended care unit of a community hospital tracked impacts for 21 months after the intervention and found no decrease in injuries from repositioning (Engst et al., 2005). In fact, more than half the staff in the intervention ward preferred to reposition patients manually with the help of other staff rather than use a lift.

More research is needed to understand whether or not ceiling lifts can reduce staff injuries from repositioning patients. An evaluation of insurance records (2000–2001) from seven hospitals found that 17.9% of reported injuries from hospital workers were the result of repositioning patients, which was the highest single cause of injury (Fragala & Bailey, 2003).

Comprehensive Patient Handling Programs

The majority of previous studies have focused on comprehensive patient lifting programs without isolating the independent effect of mechanical lifts. All of these studies support the importance of changing both the culture and the physical environment. A case study from a 525-bed nursing home shows impressive results from the implementation of a comprehensive strategy, which included protocol changes, training, and regular maintenance of equipment in addition to making mechanical lifting devices available (Brophy, Achimore, & Moore-Dawson, 2001). Results showed a reduction in the average annual costs attributed to low-back injuries from $201,000 to $91,000. In another nursing home study, Garg and Owen (1992) examined an ergonomic intervention strategy, which selected patient transferring devices that produced less physical stress for nursing personnel. This intervention also included training nurse assistants to use these devices and modifying toilets and shower rooms. This ergonomic intervention resulted in a reduction in back injuries of almost 50%, from 83 per 200,000 work hours to 47 per 200,000 work hours, and a reduction in physical stress and risk of low-back pain to nursing personnel.

Specialized Devices

One study found that strain on the backs of nursing staff could be reduced simply by providing slings to assist in moving patients from one seat to another, which also decreased capital outlay (Elford & Straker, 2000). However, the researchers measured only the spinal strain on nurses with and without slings; they did not estimate the impact in terms of reduced injuries or cost. Another laboratory study evaluated different pieces of equipment used to assist with bathing and how they affected the postural load on caregivers. Results showed that the adjustable shower chair, the adjustable bath, and the adjustable shower trolley caused the least stress on postural load, and the fixed shower chair and trolley caused the most postural stress (Knibbe & Knibbe, 1996).

Contradictory Evidence

It should be noted that not all of the previous studies found a conclusive link between the provision of mechanical lifting aids and the reduction of back injuries. One study in the United Kingdom did not reach significant findings, perhaps owing to the research design: the control hospital ended up implementing a patient handling program halfway through its research and the program implemented at its intervention hospital was not very robust. It was unclear what kind of hoists were used and how many of them were provided; the focus appears to be on training and other assistive device, such as sliding sheets (Smedley et al., 2003).

A Canadian study did not show differences in the rate and cost of injuries in wards with and without mechanical lift devices, but it did find that staff with access to assistive devices reported improved comfort, an increased sense of safety, and decreased fatigue (Yassi et al., 2001). In contrast, a 2005 study found that staff in the ward without ceiling lifts felt less stressed about their jobs and less worried about making mistakes than did the intervention group that had ceiling lifts, despite the fact that 96% of the staff members in the intervention group reported that the ceiling lifts made their jobs easier. One possible explanation for this is that using ceiling lifts to transfer patients took more time than manual lifts and transfers, and this additional time might lead to the perception of a more hectic work environment (Engst et al., 2005).

On the other hand, despite the mostly consistent positive impacts of mechanical lifts, many studies found that staff often declined to use the lifts for a variety of reasons (e.g., it takes more time and requires more space, lifts are not conveniently located, etc.) and the presence of lifts does not ensure their adoption (Chhokar et al., 2005; Evanoff et al., 2003; Joseph & Fritz, 2006; Li et al., 2004). Therefore, special attention should be paid to changing the workplace culture, such as providing training and enforcing a no-lift policy. Overall, the literature showed that comprehensive safe-patient-handling programs are important for reducing staff injuries; having mechanical lifts that are readily available and easy to use is a key component of successful programs.

Decreasing Staff Stress

Summary of Evidence and Recommendations

Healthcare providers, especially nurses, experience a high level of work stress (Jayaratne & Chess, 1984; Pines & Maslach, 1978; Siefert, Jayaratne, & Chess, 1991; Tummers, Janssen, Landeweerd, & Houkes, 2001). Several studies indicate that high workplace stress contributes to employee burnout and an intention to leave the job (Barrett & Yates, 2002; Pines & Maslach, 1978; Topf & Dillon, 1988). Registered nurses have an annual turnover rate averaging 20% (Joint Commission, 2002). Stress is a particular problem as nurses approach the possibility of retirement: 55% of nurses surveyed, predominantly managers, reported they intended to retire between 2011 and 2020 (Hader, Saver, & Steltzer, 2006). Auerbach, Buerhaus, and Staiger (2007) recently estimated that the U.S. shortage of registered nurses will increase to 340,000 by the year 2020. Although this is substantially less than the forecast made in 2000 predicting a shortfall of 800,000 registered nurses, the authors note that the nursing shortage is expected to increase to three times the size of the current shortage (Auerbach et al., 2007).

Despite convincing evidence on the negative impact of stress on healthcare workers, especially ICU nurses, relatively few studies have examined how the physical environment contributes to staff stress. Environmental factors associated with stress include noise, light, and single– versus multibed patient rooms. Noise is the most frequently studied environmental factor related to stress in hospitals, and it can be reduced by environmental approaches such as using high-performance, sound-absorbing materials. A few studies have documented the importance of light in modu lating circadian rhythms and thereby improving the adjustment to night-shift work among staff. The administration of bright light in staff work areas can be useful to alleviate stress among night-shift nurses, but the specific design implications should be further examined. Finally, survey research in NICUs found that single-bed patient rooms were perceived to be less stressful for both family and staff than open-bay multibed rooms (Harris, Shepley, White, Kolberg, & Harrell, 2006).

Severity of Staff Stress

Several studies have examined the effects of stress on healthcare workers, especially nurses working in intensive care settings (Corr, 2000; Fischer, Calame, Dettling, Zeier, & Fanconi, 2000a, 2000b; Le Blanc, de Jonge, de Rijk, & Schaufeli, 2001; Sexton, Thomas, & Helmreich, 2000; Smith et al., 2001). Oehler and Davidson (1992) found acute care nurses had higher levels of job stress and *burnout* than nurses in nonacute settings. Fischer et al. (2000a, 2000b) studied stress in ICU staff by measuring levels of the stress hormone cortisol. They found that stress-related cortisol surges occurred frequently in a sample of 112 nurses and 27 physicians in NICUs and PICUs.

Stress affects *performance*, especially for novices. For example, Smith et al. (2001) examined the relationship between psychological stress and performance by studying 45 novice registered nurses in ICUs. They found that nurses in a high state of anxiety performed less well in endotracheal suctioning than their more relaxed peers. This implies that nurses with high anxiety may be at risk for medical errors and poor performance, in addition to higher burnout and attrition.

Environmental Factors Affecting Stress

Although there is considerable evidence on the negative effects of stress on healthcare workers, relatively few studies have examined how the physical environment contributes to staff stress. Several descriptive studies on staff stress have assessed the possible effects of the characteristics of intensive care environments, such as blinking lights, alarms, and equipment noise (Corr, 2000; Donchin & Seagull, 2002; Dyson, 1999). A review paper by Corr (2000) identified the healthcare physical environment as one of the causes of occupational stress, along with the job itself and the organization. Several studies of nonhealthcare workplaces such as commercial offices have found that environmental factors associated with stress include noise, crowding, poor ambient conditions (light, air quality, and temperature), and lack of control over the environment, especially the inability to regulate social conditions and achieve privacy when desired (Baum, Singer, & Baum, 1981; Evans & Cohen, 1987). However, comparatively little research has evaluated the impact of these various environmental factors on staff stress in healthcare settings.

Reduce staff stress by controlling noise. *Noise* is the most frequently studied environmental factor related to stress in hospitals. However, much research has examined the effects of noise on patients, and few studies have focused on its impact on healthcare staff. Survey research has found that staff perceived higher sound levels as stressful and interfering with their work (Bayo, Garcia, & Garcia, 1995; Norbeck, 1985). More importantly, Topf and Dillon (1988) found that noise-induced stress correlates with reported emotional exhaustion or burnout among critical care nurses. A quasi-experimental study by Blomkvist et al. (2005) in Sweden demonstrated the positive impact of a single environmental factor—sound-absorbing ceiling tiles (versus sound-reflecting ones)—on the perceived reduction of stress by the same group of coronary intensive care nurses over a period of months. Nurses perceived significantly lower work demands and reported less pressure and strain when the sound-absorbing tiles were in place. A survey by Harris et al. (2006) in NICUs has found that staff perceived a unit with single-patient rooms to be less stressful for both family and staff than an open-bay unit, owing to better privacy and control over the environment with respect to noise, light, temperature, and traffic.

Reduce staff stress with light. Several studies have documented the importance of light in reducing depression (see Reducing Depression), modulating circadian rhythms, and improving sleep quality (see Improving Patients' Sleep). By controlling the body's circadian system, appropriate exposure to intermittent bright light also aids the adjustment to night-shift work among staff, as demonstrated by several studies (Baehr, Fogg, & Eastman, 1999; Boivin & James, 2002; Crowley, Lee, Tseng, Fogg, & Eastman, 2003; Horowitz, Cade, Wolfe, & Czeisler, 2001; Iwata, Ichii, & Egashira, 1997; Leppamaki, Partonen, Piiroinen, Haukka, & Lonnqvist, 2003). One study with 87 female night-shift nurses examined whether repeated, brief exposure (4x 20 minutes) to bright light (over 5,000 lux) during night shifts improved subjective well-being during and after night work (Leppamaki et al., 2003). Results showed that light significantly alleviated the subjective distress associated with nightshift work, in both summer and winter. Bright light (over 2,500 lux) is used for the treatment of seasonal affective disorder in winter (Partonen & Lonnqvist, 1998). A recent study by Partonen and Lonnqvist (1998) found that bright light exposure appears to have a positive effect on mood even in healthy people.

Another study found that staff with more than three hours of *daylight* exposure during their shift had higher job satisfaction and less stress than staff with less daylight exposure. However, the findings are complicated by the factor of types of nursing activities: Nurses from ICUs, EDs, or ORs were mostly exposed to daylight for less than 3 hours, while nurses from inpatient units mostly had an exposure of more than 3 hours (Alimoglu & Donmez, 2005). More research is needed to understand the impact of natural light on staff stress.

Increasing Staff Effectiveness

Summary of Evidence and Recommendations

Jobs by nurses, physicians, and other healthcare workers often require a complex choreography of direct patient care, critical communications, charting, accessing technology and information, and other tasks. Many hospital settings have not been redesigned, although jobs have been changed, and as a result, hospital environments often increase staff stress and reduce effective care delivery. The challenge of maintaining staff effectiveness will be increasingly important as the nurse shortage mounts and the aging population increases the demand on the healthcare system. While much research in the hospital setting has been aimed at patients, there is a growing and convincing body of evidence suggesting that improved hospital design can make the jobs of staff easier. The physical environment interventions that have been shown to affect staff effectiveness include unit configuration, noise, and other distractions. Lighting levels may also have an impact on staff effectiveness, but relevant studies are still limited.

Unit Configuration

Workplace design that reflects a closer alignment of work patterns and the physical setting, such as the redesign of a pharmacy layout, has been shown to improve workflow, reduce waiting times, and increase patient satisfaction with service (Pierce, Rogers, Sharp, & Musulin, 1990).

According to one study of nursing staff, walking accounted for 28.9% of work time and was ranked second among various activities, following patient-care activities that accounted for 56.9% of work time (Burgio, Engel, Hawkins, McCorick, & Scheve, 1990). At least four studies have shown that the *type of unit layout* (e.g., radial, single corridor, double corridor) influences the amount of walking among nursing staff (Shepley, 2002; Shepley & Davies, 2003; Sturdavant, 1960; Trites, Galbraith, Sturdavant, & Leckwart, 1970), and two studies showed that time saved from walking was translated into patient-care activities and interaction with family members (Trites et al., 1970). Sturdavant (1960) found that fewer trips were made to patient rooms in radial units, because nurses were able to better supervise patients visually from the nursing station, although the average time spent with patients was the same in radial units as in single-corridor designs. Shepley and Davies (2003) found that nursing staff in the radial unit walked significantly less than staff in the rectangular unit (4.7 steps versus 7.9 steps per minute). However, they also noted that radial designs might provide less flexibility in managing patient loads. In addition, the majority of the staff surveyed preferred to work in the radial units.

Some studies showed that *decentralized nurse stations* reduced staff's walking time and increased patient-care time, especially when supplies were also decentralized and placed near the nurse stations (Hendrich, 2003; IOM, 2004). The location of supplies is particularly important. Centralized location of supplies could double staff walking and substantially reduce care time irrespective of whether nurse stations were decentralized (Hendrich, 2003). Other studies that compared delivery times in centralized and *decentralized pharmacy systems* found that medication delivery times were reduced by more than 50% when using decentralized distribution systems (Hibbard, Bosso, Sward, & Baum, 1981; Lomonte, Besser, & Thomas, 1983; Reynolds, Johnson, & Longe, 1978).

By shifting over to an *acuity-adaptable model* for cardiac-care patients, Clarian Health's Methodist campus reduced the number of patient transfers by 90%, and thereby reduced the amount of nursing time expended on this "nonvalue" activity (Hendrich et al., 2004). Methodist Hospital also introduced decentralized nursing stations and supply centers. Researchers observed a reduction in staff time spent walking to get supplies and a resulting increase in nursing time, although this change was not quantified in the article. Another interesting finding was that they were able to accommodate a greater number of patient days with fewer beds, with 56 acuity-adaptable beds postintervention versus a total of 63 beds preintervention (Hendrich et al., 2004).

The *co-location of similar services* can result in better coordination of caregivers. Gilleard and Tarcisius (2003) found this to be the case in a pediatric unit in Hong Kong that was redesigned to put all physical therapy needs (e.g., speech therapy, physiotherapy, occupational therapy) in one large room. Surveys showed that both staff and patients preferred the consolidated arrangement over the previous distributed model.

Noise and Distractions

Noise levels can be high in hospital environments and noise is recognized as a distraction and stressor for staff, resulting in reduced productivity. Hospital staff often complain that noise levels make their work more difficult, particularly when it comes to monitoring patients' vital signs (Sanderson et al., 2005; Zun & Downey, 2005).

ED personnel experience especially high levels of ambient noise. Previous studies have confirmed that it can be difficult for staff members to assess patients' breathing and heartbeat in noisy and moving environments such as ambulances and helicopters (Zun & Downey, 2005). Despite these complaints, a recent study tested the ability of hospital staff to measure patients' heart and lung sounds under high ambient noise conditions (90 dB), and found that the majority of the staff (>90%) had no problem accurately detecting these sounds using standard equipment (Zun & Downey, 2005). The study involved 104 participants, ranging from attending physicians to technicians, and subjects were exposed to noise levels that were over 20 dB higher than the peak volume in a study of four EDs in Phoenix, Arizona. However, noise often has chronic rather that acute effects on performance and stress. Some studies such as those by Blomkvist and colleagues (2005) have identified long-term negative effects of noise on staff.

Loud ambient noise is the source of significant complaints in the OR (Sanderson et al., 2005). Studies have found noise levels in operating theatres to be 80–85 dB for a background level with intermittent spikes of 110–115 dB (Moorthy et al., 2004). However, not all studies indicate that a noise level of 80–85 dB is problematic. A controlled study of 12 surgeons performing laparoscopic procedures on a test module under various noise conditions (80–85 dB, both with music and under quiet conditions) found no impact of noise on the quality of performance or time taken to perform the procedure (Moorthy et al., 2004). But this study did not evaluate the impact of high peaks of intermittent noise. More research is needed to evaluate the impact of noise on communication among staff, particularly in ORs and EDs.

In addition, the typical noise produced by talking, equipment, and procedures may be compounded by noise from music, which may be played in the OR for a variety of reasons. In one U.K. survey, 72% of anesthesiologist respondents reported that music was regularly played in the OR, although 51% found music distracting and 26% found that music reduced their vigilance (Hawksworth, Asbury, & Millar, 1997). To test whether and how music plays a role in the performance of anesthesiologists, Sanderson and colleagues (2005) asked 24 participants with no medical or physiological training to monitor and report vital signs from a simulated patient using visual and auditory displays. Participants were tested under three auditory conditions: no music playing, classical music playing, and rock music playing. While participants believed that completing the task while listening to classical music was more enjoyable, a majority of participants (16 of 24) believed that the task itself was easier when completed in silence. However, the presence of music appeared to help participants to gauge correctly the direction of trends in vital signs, which were provided by the auditory display. Sanderson and colleagues speculated that this effect was because the music provided a metrical standard against which the participants could compare auditory data. It still remains to be answered whether any of these findings can be generalized to anesthetists, surgeons, or healthcare workers in general. At least one study casts doubt on the ability to generalize such findings from nonsurgeons to surgeons, and it suggests that surgeons may acquire a certain ability to block out extraneous noise while in the OR (Moorthy et al., 2004).

Surgeons are less adept when they are required to process healthcare tasks and respond to auditory distractions at the same time. In Goodell et al.'s (2006) study, 13 participants, consisting of surgical residents and medical students, were asked to perform a laparoscopic task under an uninterrupted control condition and an interrupted experimental condition, where participants were required to solve a number of arithmetic problems while performing the procedure. While the quality of the participants' work did not suffer because of cognitive distractions, the time spent on the task rose significantly during the interrupted condition. In some cases, the presence of interruptions increased the time for a given procedure by one third. Though it is not an explicit finding, this suggests the possibility that designs that minimize intrusions, particularly while surgeons are operating, may speed up a given procedure.

In short, while high noise levels are often reported as a problem by hospital staff, it appears that, with few exceptions, staff members are able to avoid the adverse effects of noise on their performance quality, although the time needed for procedures tends to increase. It is important to note that most of these studies were conducted using recorded hospital noise with constant volume; it is unclear whether staff can cope with sounds with startling volume changes (which occur frequently in hospital settings) as effectively. Overall, it is clear that the long-term effects of high levels of ambient noise on staff are troubling; although the noise may not directly hamper staff performance, the cumulative effects of stress may lead to adverse outcomes.

Impact of Other Environmental Factors on Staff Effectiveness

Other aspects of the environment, such as *lighting levels* and *auditory or visual distractions,* can also affect staff effectiveness when performing critical tasks such as dispensing medical prescriptions. There have been studies in manufacturing showing a positive effect of higher lighting levels on the speed of production (Juslen, Wouters, & Tenner, 2007). However, none that was specifically related to healthcare environments or tasks was identified. A small pilot study was conducted in a nursing home to evaluate the usefulness of providing light-emitting diode lighting triggered by motion sensors for nighttime lighting. The 17 staff members in the study reported that they found these lights convenient and useful for conducting nighttime rounds without disturbing residents' sleep (Taylor, 2005). There are several studies that have evaluated the effect of bright light (2,500 lux) and set sleep schedules on staff working the night shift (Horowitz et al., 2001). These studies report that the most significant positive effect is seen only when these factors are used in combination. Once again, such findings confirm that environmental interventions are most effective when paired with cultural or behavioral programs.

Increasing Staff Satisfaction

Summary of Evidence and Recommendations

Excellent care will hardly happen with dissatisfied hospital staff. Job satisfaction is known to be influenced by many nonphysical working conditions, such as autonomy (O'Rourke, Allgood, VanDerslice, & Hardy, 2000), compensation (Best & Thurston, 2006), and performance (Douglas, Meleis, Eribes, & Kim, 1996). Lack of support from the physical environment can make already stressful working conditions worse. Investments in the environment to increase staff satisfaction could potentially reduce the cost of staff turnover, which can cost more than $62,100 per nurse replaced (Jones, 2004). However, not many studies have examined the effects of environmental factors on job satisfaction. Natural light is one of the exceptions.

Natural Light

Mrockzek, Mikitarian, Vieira, & Rotrius (2005) conducted an Internet survey of staff working in a newly constructed facility and found that natural light in the new facility had the most positive environmental impact on work life, followed by live music in the atrium. Another study found that staff with more than 3 hours of daylight exposure during their shift had higher job satisfaction than staff with less daylight exposure. However, the findings are complicated by the types of nursing activities performed by each group (Alimoglu & Donmez, 2005). In addition, new healthcare facilities might not increase job satisfaction if they are not carefully designed. In a study comparing an old and a new ward in a mental healthcare facility, Tyson, Lambert, and Beattie (2002) concluded that the new ward resulted in no increase in job satisfaction, probably owing to the isolation of nurses caused by the larger space and separated observation wings, and understaffing in the new acute ward.

Conclusions and Design Recommendations

This study reviewed the literature linking hospital physical environments with healthcare outcomes, and identified a number of design strategies and interventions that can influence outcomes. The main body of this paper was organized by type of healthcare outcome. However, designers and healthcare workers often face the question of whether to employ specific design strategies or interventions. Therefore, the following sections discuss specific design measures and the improved outcomes that can be expected from them. Table 1 provides an overview of the relationships between design factors and healthcare outcomes. It should be noted that some of the relationships indicated in this table have not been directly tested by empirical studies, but they have been supported in an indirect way by strong available evidence.

Single-Bed Rooms

The design intervention that positively affects the largest number of outcomes in a hospital setting is the provision of single-bed patient rooms. The value of single-bed rooms has been acknowledged by the AIA after extensive research and has been included in the *2006 Guidelines for Design and Construction of Health Care Facilities* (AIA & FGI, 2006). Strong evidence indicates that single-bed rooms improve the following outcomes:

TABLE 1:
SUMMARY OF THE RELATIONSHIPS BETWEEN DESIGN FACTORS AND HEALTHCARE OUTCOMES

Healthcare Outcomes / Design Strategies or Environmental Interventions	Single-bed rooms	Access to daylight	Appropriate lighting	Views of nature	Family zone in patient rooms	Carpeting	Noise-reducing finishes	Ceiling lifts	Nursing floor layout	Decentralized supplies	Acuity-adaptable rooms
Reduced hospital-acquired infections	**										
Reduced medical errors	*		*				*				*
Reduced patient falls	*		*		*	*			*		*
Reduced pain		*	*	**			*				
Improved patient sleep	**	*	*				*				
Reduced patient stress	*	*	*	**	*		**				
Reduced depression		**	**	*	*						
Reduced length of stay		*	*	*							*
Improved patient privacy and confidentiality	**				*		*				
Improved communication with patients & family members	**				*		*				
Improved social support	*				*	*					
Increased patient satisfaction	**	*	*	*	*	*	*				
Decreased staff injuries								**			*
Decreased staff stress	*	*	*	*			*				
Increased staff effectiveness	*		*				*		*	*	*
Increased staff satisfaction	*	*	*	*			*				

* Indicates that a relationship between the specific design factor and healthcare outcome was indicated, directly or indirectly, by empirical studies reviewed in this report.

** Indicates that there is especially strong evidence (converging findings from multiple rigorous studies) indicating that a design intervention improves a healthcare outcome.

Hospital-Acquired Infections. The use of single-patient rooms reduces airborne, contact, and waterborne transmission of hospital-acquired infections by increasing isolation capacity, facilitating the thorough cleaning of rooms and the maintenance of air quality, and also possibly increasing hand-washing compliance by healthcare workers.

Patient Sleep. Patients in single-bed rooms benefit from increased privacy and the reduction in noise from roommates, visitors, and healthcare staff. These factors improve sleep and facilitate the healing process.

Patient Privacy. Single-bed rooms help protect auditory and visual privacy compared with multibed rooms. The absence of a roommate in hospital rooms helps prevent privacy breaches during discussions between patients and care providers. Patients in single-bed rooms are more willing to provide personal information to care providers, which facilitates diagnosis and treatment.

Communication with Patients and Families. Because of enhanced auditory privacy, single-bed rooms can improve communication among patients, families, and care providers. Patients in single-bed rooms report greater satisfaction with communication from nurses and physicians compared with patients in multibed rooms.

Social Support. Compared with multibed rooms, single-bed rooms provide enhanced privacy, encourage family visits and social interaction, and are more likely to provide space to accommodate visiting relatives and friends.

Staff Stress. Staff also appreciates the benefits of single-bed rooms and reports finding them less stressful than multibed or open-bay settings.

Patient Satisfaction. Considering all the above-mentioned benefits, it is no surprise that patients are more satisfied with their hospital stays when they are placed in single-bed rooms.

Access to Daylight and Appropriate Lighting

The quality and quantity of daylight exposure and artificial lighting is associated with several patient and staff outcomes in healthcare settings. Access to daylight is important for both staff and patients. For patients, it has been found to reduce pain and the incidence of depression, and for certain types of patients, it also may reduce length of stay. For staff, access to daylight contributes to higher satisfaction. Therefore, site planning and the orientation of healthcare facilities should be carefully considered to ensure sufficient daylight and avoid situations where some buildings block light for others. Larger windows in patient rooms not only provide natural light, but they also have the potential benefit of offering views of nature and should be considered in the design process.

The amount and timing of light in healthcare settings should be tailored to the activities that take place in them. In general, sufficient lighting is beneficial to both patients and staff. Bright lighting is preferred in areas where staff performs critical tasks such as medication dispensing.

Medical Errors. Research has found that medication-dispensing errors are lower when the level of work-surface lighting is relatively high, compared to situations with lower levels of lighting. While other areas of the hospital have not been tested, it is logical to infer that bright lighting would also be useful in other places where precision is called for.

Pain. Exposure to natural light has been found to reduce patients' pain and the amount of pain medications that they use. Buildings should be carefully designed so that patient rooms can have abundant natural light.

Patient Sleep. As a major contributor to normal circadian rhythm, the amount of light that patients are exposed to at different times of day can affect sleep quality. During the day, patients should be exposed to adequate natural light or bright artificial lighting when natural light is not available. At nighttime, if possible, the light in patients' rooms should be dimmed long enough to ensure good sleep.

Depression. A considerable body of rigorous evidence indicates that exposure to light—daylight or bright artificial light—is effective in reducing depression and improving mood. These findings underline the importance of building orientation and site planning in new healthcare projects.

Length of Stay. Research on patients suffering from depression found that patients in rooms with more morning daylight had shorter lengths of stay than patients in rooms without morning sunlight.

Communication with Patients and Families. Research on counseling rooms suggests that people feel more comfortable talking and talk longer in rooms with dim lighting as compared to similar rooms with bright lighting.

Patient Satisfaction. Adequate lighting has been identified as one component affecting patients' overall satisfaction with their hospital stays.

Staff Satisfaction. Access to sufficient natural light is one of the few physical environmental attributes that has been linked by research with higher staff satisfaction. This finding suggests that natural light is also needed in staff working areas.

Family Zone in Patient Room

While single-patient rooms have the potential to affect the largest number of outcomes in hospital settings, some of the benefits may be facilitated by the availability of appropriate family zones within the room.

Social Support. Evidence indicates that single-patient rooms encourage family presence by providing more space and privacy and accommodating patient-family interactions, compared with multibed rooms. It is important to make sure that single-patient rooms include appropriate family zones and comfortable furniture to encourage family members to stay longer and provide more social support to patients.

Patient Falls. Providing family zones can encourage family members to remain longer in patient rooms. As a result, timely help is available from family members to assist patients with getting in and out of the bed, which may reduce the frequency of patient falls.

Noise-Reducing Finishes

Hospitals are noisy places with numerous sources of noise, and historically they have been designed with sound-reflecting surfaces that worsen acoustic conditions and enable noises to echo and propagate over large areas. Research has found that the use of noise-reducing finishes such as high-performance sound-absorbing ceiling tiles can reduce the noise in hospitals and benefit both patients and staff.

Patient Sleep. Getting a good night's sleep is very important to patients' healing processes. Studies have found that the noise level in many hospitals is quite high even at night and that noise is a major cause of awakenings and poor sleep. For this reason, measures should be taken to reduce the reverberation time, sound propagation, and noise intensity level in patient rooms.

Patient Privacy. The use of sound-absorbing materials can also enhance patient privacy by reducing sound propagation and privacy breaches. When single-bed rooms are not available, as in many EDs, hard-wall partitions rather than curtains should be used to separate bed spaces; these should be extended all the way up to the support ceiling or deck to protect speech privacy.

Patient Satisfaction. Noise is one of the factors of the ambient environment that patients complain about most frequently. Research found that a reduced noise level in patient rooms has a positive impact on patient satisfaction. Patients treated in spaces with good acoustic performance considered staff attitude and care quality to be much better than those in spaces with poor acoustics.

Patient Stress. In addition to worsening sleep quality, noise elevates psychological and physiological stress in patients. The use of sound-absorbing materials in patient rooms, in combination with reducing noise sources, can create a less stressful environment for patients.

Staff Stress. Limited research has focused on the effects of noise on staff. A recent study found that improved room acoustics (facilitated by using sound-absorbing materials) positively affected the staff's perception of work demands and lowered their work pressure and strain.

Views of Nature

Considerable research has examined the psychological and physiological effects of viewing real and simulated nature. Most available evidence is related to the impact of nature views on patients. There is also limited evidence suggesting that staff experience restorative benefits from views of nature or exposure to gardens.

Pain. Nature has been determined to be an effective positive distraction, which can reduce the perception of pain and thereby reduce the use of pain medications. Some studies combined simulated views of nature with nature sounds or classical music; these studies demonstrated greater impact on pain reduction, compared with when auditory distraction was not available.

Length of Stay. A direct relationship between exposure to nature views and reduced length of stay in a study of patients recovering from abdominal surgery was found in one study. More research in diverse settings with various types of patient populations is needed to examine the contribution of nature views to the overall healing process and their effect on length of stay.

Patient Stress. Strong studies have found that exposing patients to nature lessens stress and anxiety.

Minimizing Negative Distractions for Healthcare Workers

Whereas positive distractions such as nature can help alleviate patient pain and stress, negative distractions (such as noise) in healthcare staff workplaces will lower work efficiency and possibly increase the incidence of medical errors.

Staff Effectiveness. Distractions during surgery can slow the progress of procedures. Interruptions from staff can result in delays in activities and thereby reduce the productivity of an already stressed staff.

Medical Errors. Distractions during critical tasks, such as preparing medications, can result in errors, which ultimately affect patients. However, the evidence shows that design strategies such as using sound-absorbing materials to reduce noise, and providing bright lighting at work stations can help minimize distractions, reduce medical errors, and improve work efficiency.

Acuity-Adaptable Rooms

There is increasing interest in acuity-adaptable rooms, but their use in real projects is still limited. As the number of hospitals with acuity-adaptable rooms grows, there will be greater opportunity to study their impact on patients and staff. Evaluation of the concept and its implementation suggest that these rooms reduce transfers, and may reduce the incidence of patient falls and medical errors and increase patient satisfaction.

Patient Falls. Acuity-adaptable patient rooms can minimize the need for costly patient transfers.

Medical Errors. Some medical errors originate from the delays, communication discontinuities, loss of information, and changes in computers or systems associated with the patient transfer process. The use of acuity-adaptable rooms can lessen the number of patient transfers and the medical errors that may occur during transfer.

Patient Satisfaction. In some recent studies, the provision of acuity-adaptable rooms was accompanied by improvements in predictive indicators of patient satisfaction. There were also improvements in quality of care and operational cost.

Looking Forward

EBD is a rapidly evolving and increasingly rigorous field. Hospital owners and designers have to make very important decisions about how hospitals will be built based on the information and knowledge available. It is clear from this review that there is a growing amount of sound research to support the application of certain specific design characteristics to improve healthcare outcomes. This paper is intended to make that evidence more accessible to practitioners, and to identify needs and directions for future research.

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