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The Role of the Physical and Social Environment in Promoting Health, Safety, and Effectiveness in the Healthcare Workplace

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Abstract

Objective: To examine how the physical environment, along with other factors such as culture and social support, impact (a) the health and safety of the care team, (b) effectiveness of the healthcare team in providing care and preventing medical errors, and (c) patient and practitioner satisfaction with the experience of giving and receiving care.

Methods: Literature review of peer-reviewed journal articles and research reports published in medicine, nursing, psychology, ergonomics, and architecture periodicals and books. Different combinations of keywords were used to search for articles including workforce, nurses, healthcare team, work environments, ergonomics, staff health, staff safety, medical errors, transfers, and communication.

Key findings: There is an urgent need to address the inherent problems in the healthcare workplace that lead to staff injuries and hospital-acquired infections, medical errors, operational failures, and wastage. The physical environment plays an important role in improving the health and safety for staff, increasing effectiveness in providing care, reducing errors, and increasing job satisfaction. These improved outcomes may, in turn, help in reducing staff turnover and increase retention — two key factors related to providing quality care in hospitals. However, it has become increasingly clear that efforts to improve the physical environment alone are not likely to help an organization achieve its goals without a complementary shift in work culture and work practices.

Proper design of healthcare settings, along with a culture that prioritizes the health and safety of the care team through its policies and values, can reduce the risk of disease and injury to hospital staff and provide the necessary support needed to perform critical tasks. Also, it is important to identify core systemic and facility design factors that lead to failures and wastage in healthcare, and then develop new solutions (e.g. acuity adaptability, standardized rooms) that address these problems within the context of culture changes and evolving models of care.

Conclusions: The physical environment along with social support, organizational culture, and technology can play an important role in improving health, safety, effectiveness and satisfaction of the healthcare team.

Introduction

Traditionally, healthcare environments have been organized to support the individual work efforts of practitioners in various roles and disciplines (doctors, nurses, therapists, dieticians, and many others) who work primarily in their areas of expertise and attempt to coordinate with others by orders, notes, phone calls, pages, and other methods of individual communication. Patients and families have traditionally been viewed as passive recipients of care rather than as active experts in their life and health conditions.

In contrast, a growing body of evidence demonstrates that healthcare work happens most effectively when practitioners work highly interdependently in well-functioning teams, with active participation by patients and families (McCarthy and Blumenthal 2006; Uhlig et al. 2002). As care moves from simply treating disease to healing the individual in a holistic sense–physically, emotionally, and psychologically–healthcare teams must increasingly work seamlessly together and include the patient and family as integral team members. A disconnect has arisen between the traditional, individual-centric organizational and physical infrastructure of the healthcare workplace and the way that healthcare practitioners, patients, and families optimally must work together. This manifests itself in the form of inefficiencies, communication breakdowns, occupational stress, medical errors, and other operational failures that are alarmingly common in healthcare today.

Further, the physical environment of the healthcare workplace, along with other factors such as culture and work processes, also impacts the health and safety of the healthcare workforce. According to the Peter D. Hart Research Associates' (2001) survey of registered nurses, the primary reason why nurses leave healthcare—other than for retirement —is to find a job that is less stressful and physically demanding. In a survey of nurses conducted by the American Nurses Association (2001), 76 percent of the nurses stated that unsafe working conditions interfered with their ability to provide quality care.

To understand and address these problems, it is necessary to consider the healthcare workplace as an interdependent system comprised of the physical environment, work processes, organizational culture (e.g., formal and informal values, norms, expectations, and policies, etc.), workforce demographics, and information technology (Becker 2006). Thus, it becomes important to consider the interdependencies and patterns of interaction between these elements, rather than focusing on individual elements alone. While several studies indicate that the physical environment impacts staff outcomes in healthcare settings, it is clear that a well-designed environment alone is unlikely to achieve its intent without a supportive work culture and the technology in place. Likewise, a supportive work culture such as one that promotes family and patient participation in care processes is unlikely to function successfully without the presence of design features (such as space for families in patient rooms) that make this possible. Hospital redesign and renovation projects provide the opportunity to consider how these different elements might interact. The challenge is to create settings where the physical environment, technology, and organizational culture together support ways of working that ensure health, safety, and effectiveness for all in healthcare.

The focus of this paper is on understanding how the physical environment interacts with other factors to impact the health, safety, and effectiveness of the care team in healthcare settings. The three sections in this paper examine how the physical environment, along with other factors such as culture and social support, impact (a) the health and safety of the care team, (b) effectiveness of the healthcare team in providing care and preventing medical errors, and (c) patient and practitioner satisfaction with the experience of giving and receiving care.

Improve health and safety of the care team through environmental measures

Properly designed physical environments impact the health and safety of staff by:

- Reducing infections.
- Decreasing back pain and work-related injuries.
- Reducing injuries from medical equipment.
- Improving adjustment to night-shift work.
- Lessening noise stress.

The healthcare workforce is exposed to various occupational hazards on a daily basis. They are exposed to airborne infections in the hospital as well as those acquired through direct contact with patients. Taking care of patients in the hospital is often back-breaking work with nurses required to manually lift heavy patient loads. For night-shift nurses, poorly entrained circadian rhythms and lack of sleep contribute to stress, fatigue, and health deterioration. In addition, other environmental stressors such as high noise levels, inadequate light, and poorly designed workspaces impact staff health and safety. Proper design of healthcare settings, along with a culture that prioritizes the health and safety of the care team through its policies and values, can reduce the risk of disease and injury to hospital staff and provide the necessary support needed to perform critical tasks.

Reducing infections among healthcare staff

Healthcare employees are at serious risk of contracting infectious diseases from patients due to airborne and surface contamination (Clarke, Sloane, and Aiken 2002; Jiang et al. 2003; Kromhout et al. 2000; Kumari et al. 1998; Smedbold et al. 2002). Factors such as poor ventilation and fungal contamination of the ventilation system that have been linked to the spread of nosocomial infections among patients may also impact staff. For example, one study that examined the relationship between indoor environmental factors and nasal inflammation among nursing personnel found the contamination of air ducts with *Aspergillus fumigatus* to be the source of infection (Smedbold et al. 2002). A recent study conducted in the wake of the severe acute respiratory syndrome (SARS) epidemic in China found that isolating SARS cases in wards with good ventilation could reduce the viral load of the ward and might be the key to preventing outbreaks of SARS among healthcare workers, along with strict personal protection measures in isolation units (Jiang et al. 2003).

While ventilation-system design and maintenance are critical to controlling the spread of airborne infections, infections are often spread through direct and indirect contact with patients. Ulrich and colleagues (2004), in their extensive literature review, concluded that poor handwashing compliance among staff is the primary cause of contact transmission of infections. They suggest that providing environmental supports to increase handwashing—including visible, conveniently placed sinks; handwashing liquid dispensers; and alcohol rubs—might be more successful in improving and sustaining handwashing compliance than education programs alone (Ulrich et al. 2004). They also document several studies that clearly show that nosocomial infection rates are lower in single patient rooms as compared to semiprivate rooms (Ulrich et al. 2004). These environmental measures that are linked to increased patient safety are also likely to protect staff from infection.

Reducing back pain and work-related injuries among hospital staff

Nursing work has become increasingly complex with changing technology, evolving work practices, and increasing documentation requirements. Further, nurses are growing older and the patient demographics are changing as well (Joint Commission on Accreditation of Healthcare Organizations, 2002). There is a need to redesign workplaces using ergonomic principles to reduce the physical demands on nursing staff.

Moreover, these efforts to redesign the physical workplace need to be augmented by staff education about healthcare occupational hazards and the development of a culture where staff health and safety are a top priority.

Lower back pain is a pervasive problem among nursing staff and is a result of poor fitness, long periods of standing, and efforts far exceeding workers' strengths (Brophy, Achimore, and Moore-Dawson 2001; Camerino et al. 2001; Miller et al. 2006). Patient lifting in particular is a major cause of injury to healthcare workers. According to Fragala and Bailey (2003), 44 percent of injuries to nursing staff in hospitals that result in lost workdays are strains and sprains (mostly of the back), and 10.5 percent of back injuries in the United States are associated with moving and assisting patients. Reducing injuries that result from patient-lifting tasks can not only result in significant economic benefit (reduced cost of claims, staff lost workdays), but also reduce pain and suffering among workers. Ergonomic programs, staff education, a no-manual lift policy, and use of mechanical lifts have been successful in reducing back injuries that result from patient-handling tasks (Engstand et al. 2005; Garg and Owen 1992; Gargand et al. 1991; Joseph and Fritz 2006; Millerand et al. 2006).

Back pain and work-related injuries among staff can be reduced by:

- Installing ceiling lifts and instituting a no-manual lift policy.
- Using softer floors.
- Through ergonomic evaluation of work areas.

For example, when PeaceHealth in Oregon installed ceiling lifts in most patient rooms in their intensive-care unit and neurology unit, they found that the number of staff injuries related to patient handling came down from ten in the two years preceding lift installation to two in the three years after lift installation (Joseph and Fritz 2006). The annual cost of patient-handling injuries in these units reduced by 83 percent after the lifts were installed (Joseph and Fritz 2006). This study, as well as others, has emphasized the importance of instituting a no-manual lift policy (along with the installation of mechanical lifts) in hospitals to prevent such injuries from occurring. Another environmental design feature that has been linked to reduced discomfort (particularly for the lower extremities and lower back) for workers who spend large amounts of time on their feet, is using softer floors (such as rubber floors) (Redfern and Cham 2000).

Ergonomic evaluations of the work area of different types of nursing staff might provide solutions to problems that are specific to different groups. For example, based on an ergonomic evaluation of the work area of scrub nurses in the operating room, Gerbrands and colleagues (2004) provided short-term solutions for reducing the neck and back problems experienced by this group as well as suggested guidelines for operating-room design. Some suggestions included height-adjustable footstools, better monitor placement, and ergonomically designed instrument tables to help reduce neck and back torsion experienced by these nurses as they attempted to obtain an unobstructed view of the operating field and reached for instruments on instrument tables in the operating room. Another area where additional ergonomics research is needed is in the design of computer workstations for nurses, since, with increasing documentation requirements, nurses are likely to spend more time at these workstations. The design of nursing workstations as they impact posture, readability, and visual fatigue need to be addressed in new designs.

Decreasing staff injuries from medical equipment

The nursing staff in hospitals is exposed to injuries from medical equipment and sharp instruments. Estimates from the University of Virginia's Exposure Prevention Information Network surveillance system in 1996 placed the number of injuries among healthcare workers in the United States from exposure to sharps at 600,000 (Clarke, Sloane, and Aiken 2002). While previous guidelines emphasized the use of pro-

tective devices and universal precautions, studies show that other factors such as organizational climate and nurse staffing also impact the likelihood of needlestick injuries (Clarke, Sloane, and Aiken 2002; Grosch et al. 1999). For example, nurses from units with low staffing and poor organizational climates were generally twice as likely as nurses on well-staffed and better-organized units to report risk factors, needlestick injuries, and near misses (Clarke, Sloane, and Aiken 2002). Nursing staff members are also open to risk of injury from medical equipment such as high-intensity surgical-light sources. One study found that a light source used during surgery could potentially cause retinal damage in surgical staff (Fox and Henson 1996). Identifying and removing environmental hazards are steps that can be taken to prevent injuries among nursing staff from medical equipment. The contribution of the physical environment to needlestick injuries has not been studied, but it is plausible that injury rates are higher in chaotic environments as compared to more organized environments. This is an area where additional research is needed.

Improving adjustment to night-shift work among nurses

The timing of the sleep–wake schedule and work schedule of night-shift nurses remains permanently out of phase with the natural light–dark cycle, and this causes health problems. Night-shift nurses not only experience loss of sleep and misalignment of circadian rhythms (biological events that repeat themselves at regular hours), they also suffer greater risk of gastric and duodenal ulcers and cardiovascular diseases (Horowitz et al. 2001). Further, their decreased alertness, performance, and vigilance may be responsible for more errors on the job (Smith-Coggins et al. 1997).

Several studies show that exposure to intermittent bright light during the night shift is effective in adapting circadian rhythms of night-shift workers (Baehr, Fogg, and Eastman 1999; Boivin and James 2002; Crowley et al. 2003; Horowitz et al. 2001; Iwata, Ichii, and Egashira 1997; Leppamaki et al. 2003). Exposure to bright light during the night shift may also improve mood and sleep (Leppamaki et al. 2003). In addition to bright-light exposure during the night, studies have shown that additional measures such as using dark sunglasses during the commute home and a regular early daytime sleep schedule ensure complete circadian adaptation to night-shift work (Boivin and James 2002; Crowley et al. 2003; Horowitz et al. 2001).

Lessening noise stress among staff

The effects of noise on patients are well-known. However, few studies have examined the impact of noise on healthcare staff. Ulrich and colleagues (2004) analyzed several studies that measured noise levels in hospitals and found that background noise levels in hospitals were typically in the range of 45 dB to 68 dB, with peaks frequently exceeding 85 dB to 90 dB. This is well above the values (35 dB) recommended by the World Health Organization guidelines (Berglund, Lindvall, and Schwela 1999). Staff perceive higher sound levels as interfering with their work (Bayo, Garcia, and Garcia 1995), and higher sound levels are also related to greater stress and annoyance among nursing staff (Morrison et al. 2003). Importantly, noise-induced stress in nurses correlates with reported emotional exhaustion or burnout (Topf and Dillon 1988). Blomkvist and colleagues (2005) examined the effects of changing the acoustic conditions on a coronary intensive-care unit (using sound-absorbing versus sound-reflecting ceiling tiles) on the same group of nurses over a period of months. During the periods of lower noise, many positive outcomes were observed among staff including improved speech intelligibility, reduced perceived work demands, and lessened perceived pressure and strain (Blomkvist et al. 2005).

Noise, Hospitals, & Stress

- Hospitals are extremely noisy places.
- Noise-induced stress is related to reported emotional exhaustion and burnout.
- Reduced noise results in improved speech intelligibility and reduced perceived work demands and pressures among staff.

Hospital personnel are frequently exposed to infectious pathogens and environmental hazards that compromise their health and safety. Through ergonomic interventions, as well as careful consideration of other issues such as air quality, noise, and light, it is possible to significantly impact the health of staff in hospitals.

Increase effectiveness of the healthcare team and reduce errors by designing better workplaces

The tasks performed by the healthcare team involve a complex choreography of multiple activities including direct patient care; indirect care, such as filling meds; coordination with care team members; accessing and communicating information; documentation of patient records; and other housekeeping tasks (Lundgren and Segesten 2001; Tucker and Spear 2006). Studies have shown that increased nursing time per patient results in better patient outcomes (Institute for Healthcare Improvement 2004; Tucker and Spear 2006). However, the fact remains that nurses spend less than half their time delivering direct patient care (Institute for Healthcare Improvement 2004). Nurses spend a lot of their time searching for other staff, materials, missing meds, and supplies and also are frequently interrupted during their work to address these problems (Tucker and Spear 2006). In one study, a hospital nurse was interrupted forty-three times during a ten-hour period, including ten instances when necessary materials, equipment, and personnel were unavailable (Potter et al. 2004).

Staff effectiveness is undermined by poorly designed work systems resulting in:

- Multiple patient transfers within the hospital.
- Time wasted hunting and gathering people and supplies.
- Frequent communication breakdowns.
- Medical errors.

At the root of the inefficiencies in healthcare is a physical and organizational infrastructure that is completely out of sync with the optimal practice of healthcare. It is becoming increasingly clear that poorly designed physical environments, along with other factors such as lack of social support and an unsupportive work culture, reduces the effectiveness of staff in providing care and potentially leads to medical errors.

Architects, healthcare administrators, and clinicians are increasingly working together to address the root causes of errors and wastage and to use that information while designing care environments (Reiling et al. 2004). Here, we describe some of the inefficiencies and breakdowns that typically undermine staff effectiveness in healthcare settings and the role the physical environment can potentially play in conjunction with a supportive work culture and technology infrastructure in increasing staff effectiveness and reducing errors. Architectural design responses to these problems are presented within the context of emerging operational models and technologies. It must be noted that the benefits of some of these design innovations have not yet been validated and need to be tested through rigorous research.

Patient transfers

Patients are transferred from one room to another as often as three to six times during their short stay (national average length of stay in US hospitals is 4.8 days [DeFrances, Hall, and Podgornik 2005]) in the hospital to receive the care that matches their level of acuity (Hendrich, Fay, and Sorrells 2004; Hendrich and Lee 2005). According to Hendrich et al. (2004), a typical nursing unit might transfer or discharge 40 percent to 70 percent of its patients every day. This process is extremely inefficient and leads to increased costs, reduced quality of care, and reduced satisfaction among patients (Hendrich, Fay, and Sorrells, 2004; Hendrich and Lee 2005). The delays, communication discontinuities among staff, loss of information, and changes in computers and systems that occur in the patient transfer process also contribute to increased

medical errors, loss of staff time, and productivity (Cook, Render, and Woods 2000; Hendrich, Fay, and Sorrells 2004).

To improve staff productivity and satisfaction, reduce resource waste (caregiver and fiscal), decrease errors, and improve the overall patient experience, the team at Clarian Methodist Hospital in Indianapolis, Indiana, under the leadership of Ann Hendrich, developed a novel demonstration project, the Cardiac Comprehensive Critical Care. The focus of this project was on providing different levels of care in a single room so as to minimize the need to transfer patients as their acuity level changed (Hendrich, Fay, and Sorrells 2004). These were single patient rooms with acuity adaptable headwalls–which were equipped with the gases and equipment needed to provide care as patient acuity changed. Further, nurses' stations on this unit were decentralized with additional workstations outside each patient's room. For the success of the initiative, it was also critical to change the operational model such that all nurses on the unit were trained to respond to patients with varying acuity levels. The impact of this fifty-six-bed acuity adaptable unit (twenty-eight rooms on two floors) on different outcomes was measured by comparing two years of baseline data (before the move) and three years of data after the move. Hendrich and colleagues (2004) found significant improvement postmove in many key areas: patient transfers decreased by 90 percent, medication errors by 70 percent, and there was also a drastic reduction in the number of falls.

Patients may be transferred three to six times during a short four to five day stay in the hospital. This results in:

- Increased costs.
- Reduced quality of care.
- Reduced satisfaction.
- Medical errors.
- Wastage of staff time.
- Reduced staff productivity.

The acuity-adaptable model potentially addresses this problem by reducing the need for transfers. For this model to be successful the physical design, as well as operational model, need to work effectively together

This was a path-breaking project that demonstrated the potential impact of acuity-adaptable care in dealing with patient flow and patient safety issues while at the same time improving the model of care. Since then, new hospital projects across the country have adopted this concept to differing extents. Challenges to incorporating acuity-adaptable rooms are often cultural (staffing model is dramatically different) and regulatory. There is a critical need to study the impact of acuity-adaptable rooms in other facilities to better understand how the physical and operational models work in different organizations and also to ascertain the safety advantages of acuity-adaptable rooms for other types of units and patient categories.

Hunting and gathering

Nurses spend a lot of time walking. According to an unpublished time and motion study by Hendrich and colleagues (cited in the 2004 Institute of Medicine report, *Keeping patients safe: Transforming the work environment of nurses,* pp. 251), most of nurses' time is spent walking between patient rooms, the nursing unit core, and the nurses' station. Often, this walking takes place to locate and gather supplies and equipment and find other staff members (Tucker and Spear 2006). Most older existing hospital units have centralized nursing stations with different configurations such as radial, racetrack, or single or double corridor where the nursing station is located centrally and patient rooms are located around the perimeter. This kind of arrangement necessitates frequent trips between patient rooms and the nurses' station to look for supplies, charting, filling meds, and so on. According to one study, almost 28.9 percent of nursing staff time was spent walking (Burgio et al. 1990). This came second only to patient-care activities, which accounted for 56.9 percent of observed behavior.

A few studies have examined the impact of unit layout on the amount of time spent walking (Shepley 2002; Shepley and Davies 2003; Sturdavant 1960; Trites et al. 1970), and two studies showed that time

saved walking was translated into more time spent on patient-care activities and interaction with family members. Shepley and colleagues (2003) found that nursing staff in a radial unit walked significantly less than staff in a rectangular unit (4.7 steps per minute versus 7.9 steps per minute). Two other studies also found that time spent walking was lower in radial units as compared to rectangular units (Sturdavant 1960; Trites et al. 1970). It must be noted that, in the units examined in these studies, the nursing station was centralized with rooms arrayed around it.

These studies seem to suggest that bringing staff and supplies physically and visually closer to the patients helps in reducing the time spent walking. To take this idea further, new designs are incorporating decentralized nurses' stations and alcoves outside patient rooms so that staff is distributed around the unit (as opposed to being in a single central location), closer to the patient. In the Clarian demonstration project described earlier, nursing stations with computer access and servers for supplies were decentralized. Further, additional workspace was provided outside each patient room. Also, to reduce time spent walking back and forth to the nursing station, necessary supplies were provided in each room. Hendrich and colleagues (2004) assert that the efficient unit design helped in reducing walking and supply trips, such that nursing time significantly increased allowing for a reduction in budgeted staffing care hours, while at the same time increasing time spent in direct patient-care activities.

Centralized location of supplies, however, could double staff walking and substantially reduce care time irrespective of whether nurses' stations were decentralized (Hendrich 2003). There is also anecdotal evidence that staff members who move from a centralized nursing unit to a decentralized unit often feel isolated and miss the camaraderie and support of the centralized unit. The social interactions that occur within the care team are critical for information sharing and effective communication. While the decentralized unit potentially has many benefits, it is worthwhile to consider how the design might impact staff interactions. It might be important to incorporate spaces on the unit (such as break rooms, coffee machine, etc.) where spontaneous encounters and social interaction might take place. With decentralized nursing care becoming increasingly common, there is a great opportunity to study the impact of this model on staff time spent walking, in direct patient care, as well as the nature of the interactions between patient and staff and between staff members so as to understand how these changes impact patient and staff satisfaction, communication within the care team, and staff effectiveness.

Nurses & Walking

- Nurses spend close to one-third of their time walking on the unit between patient rooms, the nursing unit core, and the nurses' station.
- This results in fatigue.
- Bringing staff and supplies closer to patients is likely to reduce time spent walking and increase time spent in direct patient-care activities.
- It is also important to consider the impact of decentralized care on staff socialization and communication.

Teamwork and communication

Healthcare practitioners are required to process different types of information and react quickly to the continuously changing conditions of their patients. Further, it is critical that practitioners from different disciplines–nurses, physicians, anesthetists, and so on–communicate vital patient information with each other to prevent replication of efforts, errors, and other operational failures (McCarthy and Blumenthal 2006; Uhlig et al. 2002). However, culturally, the practice of healthcare continues to be very individualistic, with independent practitioners gathering information and making decisions independently, noting actions in the medical record, and calling upon other practitioners only when needed (Uhlig et al. 2002). This creates an environment where communication breaks down frequently, something that is not lost on patients and their families. (Frustrated patients and families often ask caregivers "Don't you people ever

talk to each other?" [Uhlig et al. 2002]). Further, patients and families are rarely included in discussions about their health and well-being.

This practice of healthcare in silos discounts the evidence that, in healthcare as well as other work settings, learning and communication happens most effectively through frequent human contact and social interaction. Such interaction allows for the exchange of explicit knowledge (e.g., through the patient record) but also allows for team members to pick up on cues and triggers from their team members that allow them to perform their work.

Based on a conviction that better teamwork and communication were critical to improving patient safety, Paul Uhlig, MD, and colleagues have been conducting multidisciplinary collaborative rounds at the patient bedside in a cardiac surgery program in Concord, New Hampshire since 1999 (McCarthy and Blumenthal 2006). This involved the entire care team (including the patient and his/her family, bedside nurse, surgeon, nurse practitioner or physician assistant, social worker, spiritual-care counselor, clinical and home-care coordinators, a pharmacist, therapists, dietitian, and rehabilitation specialists) participating in ten-minute briefings at the patient's bedside at the start of the day. The team reviews the patient's care plan, discusses medication, and addresses anything that has gone wrong in the process in an open, blame-free environment (McCarthy and Blumenthal 2006). Following these changes, mortality rates declined, and both provider and patient satisfaction increased significantly (Uhlig et al. 2002). Also, according to Uhlig, the rounds have become a way to reorient the care team to a 'collaborative culture of interaction' (McCarthy and Blumenthal 2006).

Communication breakdowns occur frequently in healthcare practice due to the physical environmental, organizational, and technological infrastructure in healthcare facilities that focuses on supporting the individual rather than team efforts. Environments designed to support a culture of communication and collaboration might include the following features:

- Different types of spaces for interactive team work.
- Visual connections to facilitate information seeking and interaction.
- Flexible workspaces.
- Smaller unit size to foster interaction.
- Neutral spaces that minimize professional and status hierarchies (Becker 2006).

This example, as well as others, points to the importance of providing opportunities for individuals to interact with each other in the workplace for effective communication and knowledge sharing. Becker (2006) suggests that, for a culture of teamwork and communication to thrive, it may be important to provide the physical setting (as well as the technology infrastructure) that supports such behavior. Based on his research on different types of workplace settings, Becker (2006) puts forward five propositions for creating environments that support a culture of communication and collaboration (the cornerstone of a safer and more effective practice of healthcare).

1. *Eco-diversity:* Becker (2006) suggests that learning and collaboration are facilitated by providing many different types of settings within the workplace where spontaneous and planned face-to-face interactions might occur. Depending on the work style of the organization, these spaces might include staff lounges, nursing alcoves, break rooms, nursing stations, and so on.

2. *Spatial transparency:* When employees are able to see and hear what others are doing from their own workspace as well as when they move around their team, unit, or department's workspace during their daily work, they get more opportunities to model behavior, share information, and ask for and give critical feedback to team members.

3. *Functional inconvenience*: According to Becker (2006), opportunities for learning and interaction might be higher in organizations where employees do not have designated work spaces. Rather, they utilize

any available workspace to perform their work. Opportunities for chance encounters with a wider circle of people will potentially increase under such conditions.

4. *Human scale:* Opportunities for informal learning and interaction between team members might be higher when departments and teams are organized into smaller sections spatially, rather than the same-sized departments and teams occupying a larger space. This might have implications for the sizing of the nursing unit.

5. *Neutral zones:* Environmental cues such as those that convey the status of different individuals create barriers to the free flow of information and interaction (e.g., the traditional nurses' station with high counters creates a spatial and symbolic distinction between those providing and receiving care, thus potentially deterring patients and families from being active participants in the care process). Similarly, environmental cues that accentuate the hierarchies between doctors and nurses, between care provider and patient are detrimental to a culture of collaboration. Spaces that are neutral, in that they do not belong to any one group but to everyone, are more likely to facilitate open communication and interaction.

These propositions remain to be validated through empirical research. However, they provide a useful framework for understanding the role that the physical environment might play in promoting teamwork and communication in healthcare settings.

Errors

According to the Institute of Medicine report, *To Err Is Human: Building a Safer Healthcare System,* more than 98,000 people die each year in US hospitals due to medical errors (Kohn, Corrigan, and Donaldson 1999). According to Reiling and colleagues (2004), while some errors (active failures) occur at the point of service (for example, a nurse administering the wrong drug), most occur due to flaws in the healthcare system or facility design–such as due to high noise levels or inadequate communication systems.

Inadequate lighting and a disorganized chaotic environment are likely to compound the burden of stress for nurses and lead to errors. A few studies have shown that lighting levels and workplace design can impact errors in dispensing medication in pharmacies. One study examined the effect of different illumination levels on pharmacists' prescription-dispensing error rate (Buchananand et al. 1991). It found that error rates were reduced when work-surface light levels were relatively high (Buchanan et al. 1991). In this study, three different illumination levels were evaluated (450 lux; 1,100 lux; 1,500 lux). Medication-dispensing error rates were significantly lower (2.6 percent) at an illumination level of 1,500 lux (highest level), compared to an error rate of 3.8 percent at 450 lux. This is consistent with findings from other settings that show that task performance improves with increased light levels (Boyce, Hunter, and Howlett 2003). Two investigations of medication-dispensing errors by hospital pharmacists found that error rates increased sharply for prescriptions when an interruption or distraction occurred, such as a telephone call (Flynn et al. 1999; Kistner et al. 1994). Thus, lighting levels, frequent interruptions or distractions during work, and inadequate private space for performing work can be expected to worsen medication errors.

Most errors in healthcare occur due to healthcare system or facility design. Environmental factors contributing to errors:

- Low light levels.
- Inadequate private space for work.
- Frequent distractions and interruptions.
- Noisy chaotic environments.

Identifying the root cause of errors helps in developing design solutions to maximize patient safety.

The design process for St. Joseph's hospital in West Bend, Wisconsin, exemplifies how design innovation can be fos-

tered through a careful examination of latent conditions and active failures in the health system. The design process for this nonprofit eighty-bed acute-care facility was completely driven by safety principles–to reduce errors and maximize patient safety by designing against latent conditions and active failures (Reiling et al. 2004). A multidisciplinary team of experts from systems engineering, human factors, healthcare administration, medicine, pharmacy, healthcare architecture, and quality improvement participated in a learning lab where safety-driven design recommendations were developed. The design team then used Failure Modes Effects Analysis (a tool commonly used in the aviation and manufacturing industry to identify and prevent problems with product and process design) to test any latent problems with departmental adjacencies in the new design under the lens of patient safety. Further, new technology ideas were juxtaposed with equipment and potential design features to maximize the safety-driven design principles (Reiling et al. 2004).

The design that evolved as a result of this process included all single patient rooms allowing for more space for staff and families, a small alcove outside the patient room to allow visibility to patients, and a dedicated space for patient supplies and medication. Further, rooms are all standardized in layout, including furniture placement and location of supplies and equipment (Reiling et al. 2004). The purpose of these design features was to reduce the cognitive burden on the staff (from having to deal with variations from room to room) and also fatigue by reducing the need to walk long distances. St. Joseph's is currently evaluating the impact of its design on different types of outcomes including error rate, number of falls, and infection rate in the new facility. This project and others that follow this provide a model for redesigning systems to address factors that impact staff effectiveness. There is a need to carefully research whether these efforts are successful and to identify lessons learned for future design projects.

Clearly, there is now recognition that staff effectiveness and productivity cannot be improved through a piecemeal approach. Rather, it is critical to identify core systemic and facility design factors that lead to failures, and then develop new solutions that address these problems within the context of culture changes and evolving models of care.

Improve staff and patient satisfaction and morale through integrated environmental design

There is evidence that a supportive physical work environment, along with other factors such as high autonomy, low work pressure, and supervisor support, positively impacts job satisfaction and burnout among nurses (Constable and Russell 1986; Mroczek et al. 2005; Tumulty, Jernigan, and Kohut 1994; Tyson, Lambert, and Beattie 2002). Further, studies show that environments (i.e., physical environment, culture, and work processes) that include patients and families as active participants in the care process (as opposed to passive recipients of care) result in higher levels of satisfaction among patients and families (Sallstrom, Sandman, and Norberg 1987; Uhlig et al. 2002).

For example, the collaborative rounds at Concord Hospital were perceived very positively by patients and families who felt empowered by being part of the care team and comforted by the fact that the team members were all talking to each other (McCarthy and Blumenthal 2006; Uhlig et al. 2002). However, to include families in the care process, it is important to provide spaces for families in the patient room and on the unit where they can spend extended periods of time. Single rooms have clear advantage over multibed rooms in this regard due to increased privacy for patient-family interactions and more space and furniture to accommodate family presence (Chaudhury, Mahmood, and Valente 2006; Ulrich et al. 2004). A survey of nurses in four hospitals found that nurses gave high ratings to single rooms for accommodating family members, but accorded double rooms low scores (Chaudhury, Mahmood, and Valente 2006). In addition to these factors, organizational policies such as those that limit family visitation hours might influence family involvement and satisfaction with care.

Studies show that physical design changes in long-term care settings such as interior design modifications, natural elements, furniture repositioning to support social interaction, design supports for resident independence (such as large clocks, handrails, additional mirrors), orientation (large, clear signposts, and reality orientation boards), and artwork were related to improved morale and satisfaction among staff (Christenfeld et al. 1989; Cohen-Mansfield and Werner 1999; Jones 1988; Loeb et al. 1995; Parker et al. 2004). Tumulty and colleagues (1994) suggest that, if staff were allowed to make small design modifications to their existing environments, their satisfaction with their jobs might increase.

Other studies, primarily conducted in long-term care settings, suggest that smaller units contribute to reduced stress and increased staff satisfaction. A cross-sectional survey of 1,194 employees and 1,079 relatives of residents in 107 residential-home units and health-center bed wards found that large unit size was related to increased time pressure among employees and reduced quality of life for residents (Pekkarinen et al. 2004). Other studies found that small unit sizes were positively associated with increased supervision and interaction between staff and residents in a special-care unit for residents with dementia (McCracken and Fitzwater 1989). However, no consistent numbers are offered on what makes a unit large or small (Day, Carreon, and Stump 2000), and it is also not clear how these findings translate to acute-care settings. Further, even in small units, it is important to consider how the design impacts staff ability to monitor residents. Morgan and Stewart (and1998) found that, in a newly designed, low-density special-care unit with private rooms, enclosed charting spaces, and secluded outdoor areas and activity areas, staff spent increased time monitoring and locating residents.

Increase staff and patient satisfaction and morale through workplace design by:

- Incorporating patient and family spaces to support family participation in the care process.
- Design of pleasant, attractive environments.
- Smaller units with good visual access between staff and patients.

An important point that is emphasized in many of these studies is that design changes alone are not likely to impact staff behavior, satisfaction, and stress. They must be accompanied by a supportive culture and progressive work practices to result in overall beneficial outcomes for patients and staff.

Summary

There is an urgent need to address the inherent problems in the healthcare workplace that lead to staff injuries, medical errors, and wastage. The physical environment plays an important role in improving the health and safety for staff, increasing effectiveness in providing care, reducing errors, and increasing job satisfaction. These improved outcomes may, in turn, help in reducing staff turnover and increase retention, two key factors related to providing quality care in hospitals.

However, it has become increasingly clear that efforts to improve the physical environment alone are not likely to help an organization achieve its goals without a complementary shift in work culture and work practices. To summarize this discussion, some key steps that could be considered while designing supportive healthcare workplaces include:

- Identify operational and system problems that impact staff effectiveness and productivity (such as interruptions, transfers, lack of information) and develop design and care models (e.g., acuity-adaptable rooms) that effectively address these problems.
- Identify steps to promote culture change parallel to design changes to ensure effectiveness and acceptance for new innovations.

- Through the design of the environment, provide opportunities for spontaneous and planned interactions within the healthcare team.
- Provide spaces for families such that patients and families can be effectively included in the healthcare team.
- Consider installing ceiling lifts in patient rooms to reduce staff back injuries along with instituting a no-manual lift policy.
- Conduct ergonomic evaluation of staff work areas to design spaces that are supportive of staff work practices and reduce pain and injury.
- Carefully consider sources of infection and injury to staff (air, contact, and bloodborne) during design.
- Institute measures to reduce noise stress among nurses (e.g., by improving acoustic conditions on the nursing unit, education, and awareness programs).
- Consider work flows in relation to location of key spaces (patient room, nurse work space, location of equipment and supplies) with the goal of minimizing walking distances and number of trips.
- Consider locating frequently used supplies in patient rooms to minimize walking trips for staff.

While the studies described in this paper demonstrate that well-designed physical workplaces can support staff in their work and increase health and safety, there is a definite need for more research examining the effectiveness of new design innovations such as acuity adaptability, standardized patient rooms, and decentralized nursing station within the larger context of an organization's culture, technology changes, and work practices.

References Cited

American Nurses Association. 2001. *American Nurses Association/ NursingWorld.org online health and safety survey: Key findings* (Survey results). Washington, DC: American Nurses Association.

Baehr, E., L. F. Fogg, and C. I. Eastman. 1999. Intermittent bright light and exercise to entrain human circadian rhythms to night work. *American Journal of Physiology 277*:1598–1604.

Bayo, M. V., A. M. Garcia and A. Garcia. 1995. Noise levels in an urban hospital and workers' subjective responses. *Archives of Environmental Health 50*(3):247–251.

Becker, F. 2006 (under review). Organizational ecology and knowledge networks. *California Management Review*.

Berglund, B., T. Lindvall, and D. H. Schwela, eds. 1999. *Guidelines for community noise*. World Health Organization.

Blomkvist, V., C. A. Eriksen, T. Theorell, R. S. Ulrich, and G. Rasmanis. 2005. Acoustics and psychosocial environment in coronary intensive care. *Occupational and Environmental Medicine 62*:1–8.

Boivin, D., and F. James. 2002. Circadian adaptation to night-shift work by judicious light and darkness exposure. *Journal of Biological Rhythms 17*(6): 556–567.

Boyce, P., C. Hunter, and O. Howlett. 2003. *The benefits of daylight through windows*. Troy, NY: Rensselaer Polytechnic Institute.

Brophy, M. O. R., L. Achimore, and J. Moore-Dawson. 2001. Reducing incidence of low-back injuries reduces cost. *American Industrial Hygiene Association Journal 62*(4): 508–511.

Buchanan, T. L., K. N. Barker, J. T. Gibson, B. C. Jiang, and R. E. Pearson. 1991. Illumination and errors in dispensing. *American Journal of Hospital Pharmacy 48*(10): 2137–2145.

Burgio, L., B. Engel, A. Hawkins, K. McCorick, and A. Scheve. 1990. A descriptive analysis of nursing staff behaviors in a teaching nursing home: Differences among NAs, LPNs and RNs. *The Gerontologist 30*: 107–112.

Camerino, D., G. C. Cesana, G. Molteni, G. D. Vito, C. Evaristi, and R. Latocca. 2001. Job strain and musculoskeletal disorders of Italian nurses. *Occupational Ergonomics 2*: 215.

Chaudhury, H. , A. Mahmood, and M. Valente. 2006. Nurses' perception of single-occupancy versus multioccupancy rooms in acute care environments: An exploratory comparitive assessment. *Applied Nursing Research* 19:118-125.

Christenfeld, R., J. Wagner, G. Pastva, and W. P. Acrish. 1989. How physical settings affect chronic mental patients. *Psychiatric Quarterly 60*(3): 253–264.

Clarke, S., D. Sloane, and L. Aiken. 2002. Effects of hospital staffing and organizational climate on needlestick injuries to nurses. *American Journal of Public Health 92*(7): 1115–1119.

Cohen-Mansfield, J., and P. Werner. 1999. Outdoor wandering parks for persons with dementia: A survey of characteristics and use. *Alzheimer Disease and Associated Disorders 13*(2): 109–117.

Constable, J., and D. Russell. 1986. The effect of social support and the work environment upon burnout among nurses. *Journal of Human Stress 12*(1): 20–26.

Cook, R. I., M. Render, and D. D. Woods. 2000. Gaps in the continuity of care and progress on patient safety. *British Medical Journal 320*(7237): 791–794.

Crowley, S., C. Lee, C. Tseng, L. F. Fogg, and C. I. Eastman. 2003. Combinations of bright light, scheduled dark, sunglasses, and melatonin to facilitate circadian entrainment to night shift work. *Journal of Biological Rhythms 18*(6), 51–523.

Day, K., D. Carreon, and C. Stump. 2000. The therapeutic design of environments for people with dementia: A review of the empirical research. *The Gerontologist 40*(4): 397–416.

DeFrances, C. J., M. J. Hall, and M. N. Podgornik. 2005. 2003 National Hospital Discharge Survey: Advance data from Vital and Health Statistics. Hyattsville, MD: US Department of Health and Human Services, CDC, National Center for Health Statistics.

Engst, C., R. Chhokar, A. Miller, R. B. Tate, and A. Yassi. 2005. Effectiveness of overhead lifting devices in reducing the risk of injury to care staff in extended care facilities. *Ergonomics 48*(2): 187–199.

Flynn, E. A., K. N. Barker, J. T. Gibson, R. E. Pearson, B. A. Berger, and L. A. Smith. 1999. Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. *American Journal of Health Systems Pharmacy 56*(13): 1319–1325.

Fox, R. A., and P. W. Henson. 1996. Potential ocular hazard from a surgical light source. *Australasian Physical and Engineering Sciences in Medicine* 19 (1):12-16.

Fragala, G., and L. Bailey. 2003. Addressing occupational strains and sprains: Musculoskeletal injuries in hospitals. *AAOHN Journal 51*(6): 252–259.

Garg, A., and B. Owen. 1992. Reducing back stress to nursing personnel: An ergonomic intervention in a nursing home. *Ergonomics 35*(11): 1353–1375.

Garg, A., B. Owen, D. Beller, D., and J. Banaag. 1991. A biomechanical and ergonomic evaluation of patient transferring tasks: Bed to wheelchair and wheelchair to bed. *Ergonomics 34*: 289–312.

Gerbrands, A., A. Albayrak, and G. Kazemier. 2004. Ergonomic evaluation of the work area of the scrub nurse. *Minimally Invasive Therapy and Allied Technology 13*(3): 142–146.

Grosch, J. W., R. Gershon, L. Murphy, and D. Dejoy. 1999. Safety climate dimensions associated with occupational exposure to blood borne exposure in nurses. *American Journal of Industrial Medicine. 1*(Suppl. No. 1): 122–124.

Hendrich, A. 2003. *Case study: The impact of acuity adaptable rooms on future designs, bottlenecks, and hospital capacity*. Paper presented at the Impact Conference on optimizing the physical space for improved outcomes, satisfaction, and the bottom line, Atlanta, GA.

Hendrich, A., J. Fay, and A. Sorrells. 2004. Effects of acuity-adaptable rooms on flow of patients and delivery of care. *American Journal of Critical Care 13*(1): 35–45.

Hendrich, A., and N. Lee. 2005. Intra-unit patient transports: Time, motion, and cost impact on hospital efficiency. *Nursing Economic$ 23*(4): 157–164.

Horowitz, T., B. Cade, J. Wolfe, and C. Czeisler. 2001. Efficacy of bright light and sleep/darkness scheduling in alleviating circadian maladaptation to night work. *American Journal of Physiology—Endocrinology and Metabolism 281*: 384–391.

Institute for Healthcare Improvement. 2004. *Transforming care at the bedside*. Cambridge, MA: Institute for Healthcare Improvement.

Institute of Medicine. 2004. Work and workspace design to prevent and mitigate errors. In *Keeping patients safe: Transforming the work environment of nurses,* ed. A. Page, 226–285. Washington, DC: National Academies Press.

Iwata, N., S. Ichii, and K. Egashira. 1997. Effects of bright artificial light on subjective mood of shift work nurses. *Industrial Health 35*: 41–47.

Jiang, S., L. Huang, X. Chen, J. Wang, W. Wu, S. Yin, et al. 2003. Ventilation of wards and nosocomial outbreak of severe acute respiratory syndrome among healthcare workers. *Chinese Medical Journal 116*(9): 1293–1297.

Joint Commission on Accreditation of Healthcare Organizations. 2002. *Health care at the crossroads: Strategies for addressing the evolving nursing crisis*. Oakbrook Terrace, IL: Joint Commission on Accreditation of Healthcare Organizations.

Jones, R. G. 1988. Experimental study to evaluate nursing staff morale in a high stimulation geriatric psychiatry setting. *Journal of Advanced Nursing 13*: 352–357.

Joseph, A., and L. Fritz. 2006. Ceiling lifts reduce patient-handling injuries. *Healthcare Design 6:* 10–13.

Kistner, U. A., M. R. Keith, K. A. Sergeant, and J. A. Hokanson. 1994. Accuracy of dispensing in a high-volume, hospital-based outpatient pharmacy. *American Journal of Hospital Pharmacy 51*(22): 2793–2797.

Kohn, L., J. Corrigan, and M. Donaldson, eds. 1999. *To err is human: Building a safer health system*. Washington, DC: National Academy Press.

Kromhout, H., F. Hoek, R. Uitterhoeve, R. Huijbers, R. F. Overmars, R. Anzion, et al. 2000. Postulating a dermal pathway for exposure to anti-neoplastic drugs among hospital workers: Applying a conceptual model to the results of three workplace surveys. *The Annals of Occupational Hygiene 44*(7): 551–560.

Kumari, D. N., T. C. Haji, V. Keer, P. M. Hawkey, V. Duncanson, and E. Flower. 1998. Ventilation grilles as a potential source of methicillin-resistant Staphylococcus aureus causing an outbreak in an orthopaedic ward at a district general hospital. *Journal of Hospital Infection 39*(2): 127–133.

Leppamaki, S., T. Partonen, P. Piiroinen, J. Haukka, and J. Lonnqvist. 2003. Timed bright-light exposure and complaints related to shift work among women. *Scandinavian Journal of Environmental Health 29*(1): 22–26.

Loeb, M., L. Wilcox, D. Thornley, J. Gun-Munro, and H. Richardson. 1995. Bacillus species pseudobacteremia following hospital construction. *Canadian Journal of Infection Control 10*(2): 37–40.

Lundgren, S., and K. Segesten. 2001. Nurses' use of time in a medical-surgical ward with all-RN staffing. *Journal of Nursing Management 9*: 13–20.

McCarthy, D., and D. Blumenthal. 2006. *Committed to safety: Ten case studies on reducing harm to patients* (No. 923). New York: Commonwealth Fund.

McCracken, A. L., and E. Fitzwater. 1989. The right environment for Alzheimer's: Which is better—open versus closed units? Here's how to tailor the answer to the patient. *Geriatric Nursing 10*: 293–294.

Miller, A., C. Engst, R. Tate, and A. Yassi. 2006. Evaluation of the effectiveness of portable ceiling lifts in a new long-term care facility. *Applied Ergonomics 37*: 377–385.

Morgan, D., and N. Stewart. 1998. High versus low density special care units: Impact on the behavior of elderly residents with dementia. *Canadian Journal on Aging 17*: 143–165.

Morrison, W. E., E. C. Haas, D. H. Shaffner, E. S. Garrett, and J. C. Fackler. 2003. Noise, stress, and annoyance in a pediatric intensive care unit. *Critical Care Medicine 31*(1): 113–119.

Mroczek, J., G. Mikitarian, E. K. Vieira, and T. Rotarius. 2005. Hospital design and staff perceptions: An exploratory analysis. *Health Care Manager 24*(3): 233–244.

Parker, C., S. Barnes, K. McKee, K. Morgan, J. Torrington, and P. Tregenza. 2004. Quality of life and building design in residential and nursing homes for older people. *Ageing and Society 24*: 941–962.

Pekkarinen, L., T. Sinervo, M.-L. Perala, and M. Elovainio. 2004. Work stressors and the quality of life in long-term care units. *The Gerontologist 44*(5): 633–643.

Peter D. Hart Research Associates. 2001. *The nurse shortage: Perspectives from current direct care nurses and former direct care nurses*. Washington, DC: Federation of Nurses and Health Professionals.

Potter, P., S. Boxerman, L. Wolf, J. Marshall, D. Grayson, J. Sledge, et al. 2004. Mapping the nursing process: A new approach for understanding the work of nursing. *Journal of Nursing Administration 34*(2): 101–109.

Redfern, M., and R. Cham, R. 2000. The influence of flooring on standing comfort and fatigue. *American Industrial Hygiene Association Journal 61*: 700–708.

Reiling, J., B. Knutzen, T. Wallen, S. McCullough, R. Miller, and S. Chernos. 2004. Enhancing the traditional hospital design process: A focus on patient safety. *Joint Commission Journal on Quality and Safety 30*(3): 115–124.

Sallstrom, C., P. O. Sandman, and A. Norberg, A. 1987. Relatives' experience of the terminal care of long-term geriatric patients in open-plan rooms. *Scandinavian Journal of Caring Science 1*(3-4): 133–140.

Shepley, M. M. 2002. Predesign and postoccupancy analysis of staff behavior in a neonatal intensive care unit. *Children's Health Care 31*(3): 237–253.

Shepley, M. M., and K. Davies. 2003. Nursing unit configuration and its relationship to noise and nurse walking behavior: An AIDS/HIV unit case study. *AIA Academy Journal,* http://www.aia.org/aah_a_jrnl_0401_article4 (accessed May 26, 2004).

Smedbold, H. T., C. Ahlen, S. Unimed, A. M. Nilsen, D. Norbaeck, and B. Hilt. 2002. Relationships between indoor environments and nasal inflammation in nursing personnel. *Archives of Environmental Health 57*(2): 155–161.

Smith-Coggins, R., M. Rosekind, K. Buccino, D. Dinges, and R. Moser. 1997. Rotating shiftwork schedules: Can we enhance physician adaptation to night shifts? *Academic Emergency Medicine 4*: 951–961.

Sturdavant, M. 1960. Intensive nursing service in circular and rectangular units. *Hospitals, JAHA 34*: 46–48, 71–78.

Topf, M., and E. Dillon. 1988. Noise-induced stress as a predictor of burnout in critical care nurses. *Heart Lung 17*(5): 567–574.

Trites, D. K., F. D. Galbraith, M. Sturdavant, and J. F. Leckwart. 1970. Influence of nursing-unit design on the activities and subjective feelings of nursing personnel. *Environment and Behavior 2*(3): 303–334.

Tucker, A., and S. Spear. 2006. Operational failures and interruptions in hospital nursing. *Health Services Research 41*(3): 643–662.

Tumulty, G., I. E. Jernigan, and G. F. Kohut. 1994. The impact of perceived work environment on job satisfaction of hospital staff nurses. *Applied Nursing Research 7*(2): 84–90.

Tyson, G. A., G. Lambert, and L. Beattie. 2002. The impact of ward design on the behavior, occupational satisfaction and well-being of psychiatric nurses. *International Journal of Mental Health Nursing 11*(2): 94–102.

Uhlig, P., J. Brown, A. Nason, A. Camelio, and E. Kendall. 2002. System innovation: Concord Hospital. *Joint Commission Journal on Quality Improvement 28*(12): 666–672.

Ulrich, R. S., C. Zimring, A. Joseph, X. Quan, and R. Choudhary. 2004. *The role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity*. Concord, CA: The Center for Health Design.