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The Effect of Environmental Design on Reducing Nursing Errors and Increasing Efficiency in Acute Care Settings

A Review and Analysis of the Literature

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Physical environment is an important component in the acute care setting that can affect nursing and medication accuracies, as any inadequacy in physical environment would contribute to staff fatigue, stress, and burnout and result in errors. The article discusses a study conducted involving an extensive review and analysis of the literature on this topic and focus groups with various categories of staff members at three hospitals. The review demonstrates that the following environmental variables can contribute to errors in acute care settings: noise levels, ergonomics/furniture/equipment, lighting, and design/layout. Focus groups address the role of the physical environment on medication ordering, storage, delivery, dispensation, preparation, administration, and possible design responses to reduce errors. Integrating the major issues identified and the key findings from the focus groups, four design-related principles are recommended: balance between patient accessibility and reduction of disruptions, automation, minimize staff fatigue, and promoting a culture of safety.

Keywords: acute care; environmental design; nursing error; medication error

Overview

Nurses’ work in the acute care environment is physically and psychologically intense with much scope for burnout, stress, and error. Crowded,
acoustically ineffective, and poorly designed nursing stations and other health care staff work spaces within the hospital add to staff stress and may increase the risk of medical errors. Ulrich, Zimring, Quan, Joseph, and Choudhary (2004) argued that reduction of staff stress (and error) by ergonomic interventions, as well as environmental considerations (such as air quality, acoustics, lighting, etc.) can have significant impact on staff health. It can also influence staff efficiency and contribute toward patient safety. It is claimed (e.g., Harrison, 2004; McCarthy, 2004; Reiling, Breckbill, Murphy, McCullough, & Chernos, 2003; Rollins, 2004; Scott, 2004) that specific environmental conditions, such as type of lighting (artificial versus natural lighting), degree of lighting in nurses’ workspace (e.g., artificial lighting producing the effect of feeling drained and tired; inadequate lighting leading to medication error), and thermal conditions in work areas affect performance. Research has demonstrated that high noise levels in acute care environments are detrimental to work performance (e.g., Joseph & Ulrich, 2007; Topf & Dillon, 1988).

Nursing errors and efficiency can be conceptualized at two levels, “active failures” and “latent conditions” (Reason, 2000). An active failure is one that is caused by the person on the frontline (e.g., nurse administering medication on a patient, control room operator, train driver, pilots, air traffic controllers, etc.). Active failures can be attributed to human cognition and limitations of memory and thought process. The adverse effect of an active failure will be an active error, such as use of a wrong medication or incorrect dose. Latent conditions refer to failures resulting from decisions made by the management and architects. Examples include time pressure, stress, fatigue, and physical factors such as noise, lack of privacy, temperature, and so on. These issues highlight that the design of nurses’ work environments needs to be supportive of the nature of their work, and responsive to their particular needs. However, there is limited research on the effects of environmental factors on nursing staff health, effectiveness, errors and job satisfaction.

To conduct a systematic literature review on environmental factors related to nursing efficiency, error, and other outcomes, a conceptual approach (Figure 1) was used as a guide to develop research questions and to select keywords.

Medical errors result from interplay of multiple factors that include, among others, regulatory environment, organizational leadership and

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commitment, management policies and procedures, complexity of tasks involved, work culture, and physical environment. This conceptual approach is based on Reason’s (2000) conceptualization of human errors and Ulrich’s et al. (2004) identification of the effect of the physical environment on staff outcomes. The notable aspect of this approach, as espoused by Reason (2000) and others, is that instead of focusing on individual carelessness or mishandling of a task per se, it is critical to address the latent conditions of the environment, that is, underlying systems, and their faults to prevent errors. Management decisions and organizational processes, such as staff hierarchy, pattern and quality of staff communications, staff workload, work culture, and so on can effect nursing and medication errors either directly (e.g., miscommunication of medication information) or indirectly.
by creating error-producing conditions (e.g., staff fatigue leading to error). The physical environment can be operationalized into its architectural and interior design aspects to inform the structural versus nonstructural aspects of planning and design processes. Also, this distinction allows identification of features of the physical environment that could be modified in an existing facility versus decisions made in planning and design of a new facility. As with the management and organizational aspects, the physical environmental aspects could potentially affect the occurrence of errors in direct ways, for example, lack of adequate lighting causing misreading a medication label, or in indirect ways by creating error-producing conditions; for example, noise in and around nurses’ stations can cause staff stress, which in turn raises the potential for nursing error. Also, these two dimensions of the care environment can act independently or interact with each other in influencing error-producing conditions like staff stress and fatigue. Although the direct effect of the physical environment on error is critical, it is important to examine the role of the environment on mediating factors like staff stress and fatigue to better understand the latent conditions in the staff themselves. From this perspective, staff stress and fatigue, even lack of job satisfaction, are conditions arising out of the more fundamental latent dimensions of the systems, that is, organizational/management and physical environmental aspects. This conceptual approach suggests that staff stress, fatigue, and so on are the second-level latent conditions in the trajectory of nursing and medication errors.

Research questions that guided this study were

(1) What are the effects of physical environmental variables on nursing errors, nurses’ efficiency, and quality of patient care in medical/surgical nursing units?
(2) What are the effects of physical environmental variables on nurses’ job satisfaction and performance, health, and safety in medical/surgical nursing units?

An extensive review of literature was conducted in the area of health care design and medication/nursing errors, staff efficiency and safety, infection control, and patient outcomes. In this article, we provide a synthesis of the literature noting the key environmental factors related to error in health care settings. The reviewed articles, book chapters, and so on were subdivided into empirical and nonempirical categories. Articles that presented primary data from a research project were grouped under the “empirical” subcategory. Articles that were either review of other studies,
prescriptive in nature, or that covered general descriptive information were grouped under “nonempirical” subcategory. Within the nonempirical subcategory, the articles were further subdivided into “expert opinion” and “anecdotal information.” This summary is shown in Table 1. We use a “star” system to denote the quality and quantity of articles in each area, with higher number of stars indicating higher empirical evidence in that particular area. The number of stars was assigned to each of the issues based on an overall assessment of the number and quality of the empirical articles. The quality of empirical articles were examined based on the rigor of the empirical study as evidenced by aspects such as sample size, research design, tools used, and method of analysis.

Method

Several strategies were used to identify potential articles for the review. First, a keyword search in relevant databases was conducted. Second, potential studies were identified by a systematic review of issues of relevant journals in the area of health care design, management, nursing research, and infection control. The literature search demonstrated that many articles on the relationship of design to healing and innovations in hospital design are dated from 1980 and later, so this time frame was chosen for the systematic journal searches. However, relevant articles dealing with nursing units/stations and nurses’ work environment dating earlier than 1980 were also included in the review. Finally, reference lists were inspected in articles included in this review to identify literature items that dealt directly with nursing work environmental issues. In total, 204 empirical (evidence based) and 148 nonempirical (descriptive and conceptual) journal articles, books, book chapters, and reports were reviewed and analyzed. Among these 352 items, 112 were specifically on nursing and medication errors. However, the majority of these 112 items addressed organizational- and management-related issues on errors and very few directly examined the role of the physical environment on errors. As indicated earlier in the research questions, the review expanded to examine the evidence of the environment’s effect on error-producing conditions, such as staff satisfaction and performance, which in turn may have potential effects on errors. A breakdown of the reviewed items by substantive areas is provided in Figure 2.

Given the scarcity of literature specifically examining the role of the physical environment on errors in acute care settings, an exploratory empirical study with focus group interviews were conducted with selected staff
<table>
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<tr>
<th>Factors Affecting Errors in the Healthcare Environment</th>
<th>Key Issues</th>
<th>Degree of Evidence</th>
<th>Empirical Articles</th>
<th>Nonempirical Articles</th>
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<tr>
<td>Noise</td>
<td>Noise levels increasingly exceed recommended levels by World Health Organization</td>
<td>★ ★ ★ ★ ★</td>
<td>Blomkvist, Eriksen, Theorell, Ulrich, &amp; Rasmanis (2005); Ganey (2003); Graven (1997); Hilton (1985); Hodge &amp; Thompson (1990); Topf (1985); Topf &amp; Dillon (1988)</td>
<td>Berglund, Lindvall, &amp; Schwela (1999); Hosking &amp; Haggard (1999); Shumaker &amp; Reizemstein (1982); Ulrich, Zimring, Quan, Joseph, &amp; Choudhary (2004)</td>
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<td>Excess noise can result in negative symptoms for patients including stress levels</td>
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<td>Excess noise levels can increase stress levels for staff members and impair concentration and communication, resulting in errors</td>
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<td>Bright lights improve patient outcomes</td>
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<td>Exposure to sunlight results in improved health</td>
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<td></td>
<td>Increased exposure to natural light positively impacts work life of staff members</td>
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<td>Rotarius (2005); Walch, Rabin, Day, Williams, Choi, &amp; Kang (2004); Ulrich (1984)</td>
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<td>Ergonomics/ Furniture/ Equipment</td>
<td>Ergonomic design is critical to efficiency</td>
<td>★ ★ ★ ★ ☆</td>
<td>Ali et al. (2005); Bates et al. (1998); Borel &amp; Rascati (1995); Hui, Ng, Yeung, &amp; Hui-Chan (2001); Janowitz et al. (2006); Koppel et al. (2005); Rothschild et al. (2005); Schwarz &amp; Brodowy (1995); Shirley (1999)</td>
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<td>Visual and tactile discrimination should be maximized through the use of appropriate materials</td>
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<td>Carayon, Alvarado, &amp; HUndt (2003); Kroemer &amp; Kroemer (2001)</td>
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<td>Poor ergonomics are associated with higher absenteeism levels</td>
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<td>Automated medication entry systems have reduced errors</td>
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<td>Design/Layout</td>
<td>Single-occupancy rooms improve patient outcomes in comparison to double-occupancy rooms</td>
<td>★ ★ ★ ☆ ☆</td>
<td>Hendrich, Fay, &amp; Sorrells (2002); Janssen, Harris, Soolsma, Klein, &amp; Seymour (2001)</td>
<td>Hill-Rom (2002); Page (2004); Reiling &amp; Knutzen (2003); Spreckelmeyer (2004); Carayon et al. (2003)</td>
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<td>Acuity adaptable rooms result in fewer errors and shorter lengths of stay</td>
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members at three hospitals in the Pacific Northwest of the United States. Participants included various nursing, administrative, and pharmacy staff members. Three focus groups were conducted at three hospitals in the Pacific Northwest (Swedish Medical Center, Providence, St. Vincent Hospital and Providence, Portland Hospital) to specifically understand the potential role of the physical environment on medication errors. These hospitals were selected based on the research relationship established with the investigators by their participation in a previous study. Participants for focus groups were recruited through the assistance of the Directors of Patient Care Services who sent out an open invitation to the nursing staff. However, pharmacists and risk managers at each hospital were directly invited to participate in the meeting by the respective directors. Participants represented different groups of nursing staff (i.e., nurse manager, charge nurse, unit clerk, and care aide), risk managers, and pharmacists. In each focus group, the number of participants was 6 or 7, with the total number of participants being 19. The sessions were held in staff meeting rooms at the respective hospitals, with each session lasting between 90 and 120 minutes. Light refreshments were provided, and each participant was given a US$25 gift card from a local department store in appreciation of their time. The sessions focused on the following topics: most common factors contributing to medical/nursing errors, environmental factors contributing to these errors
(probes included sound/noise, walking distance, lighting, color, etc.), and suggestions for improvement of the physical environment. An interview guide was used to facilitate the discussion with the flexibility of additional relevant issues raised by the participants. The questions were pilot tested with the directors of care services at the three hospitals for relevance, appropriateness, and clarity. Focus groups were facilitated by one researcher; another researcher raised questions to seek clarification, and the research assistant served the role of the recorder. The interviews were tape-recorded, transcribed, and analyzed using a qualitative thematic analysis.

Synthesis of the Literature Review

Errors in Healthcare Settings

Medical errors may result in a patient experiencing an adverse event. According to the IOM report *To Err is Human,* adverse events occur when a patient suffers an injury that is not due to the patient’s condition but rather results from a medical intervention (Kohn, Corrigan, & Donaldson, 2000). In the Harvard Medical Practice study, the estimated incidence of adverse events was 3.7%, and most resulted in minor impairment (Brennan et al., 1991). Based on studies that have been conducted in both Colorado and Utah, it has been estimated that approximately 44,000 Americans die in hospitals each year as a result of preventable medical errors (Kohn et al., 2000). The estimated national costs of adverse events in the United States is 37.6 billion dollars, whereas the national costs of preventable adverse events has been estimated to be 17 billion dollars (Kohn et al., 2000). The highest among these is adverse drug events. Medication errors typically involve missed doses, dose errors, route errors, and duplicate errors (Bates, Boyle, Vander Vliet, Schneider, & Leape, 1995; Davydov, Caliendo, Mehl, & Smith, 2004; Leape et al., 1995). Errors often occur in physician ordering and nursing administration. Dispensing errors are associated with a high prescription volume, overwork, fatigue, interruptions, and drugs that look alike or sound alike (Hodgkinson, Koch, Nay, & Nichols, 2006). The incidence of adverse events was found to be the highest in medical intensive care units followed by surgical intensive care units, and medical and surgical general care units (Bates et al., 1995).

Both environmental and nonenvironmental variables may contribute to the occurrence of errors and adverse events in both health care and nonhealth care workplaces. The environmental variables are mostly latent...
factors. Based on the literature review, the key physical environmental variables that have the most real or potential effect on workplace errors are as follows:

- Noise
- Lighting
- Ergonomics/Furniture/Equipment
- Design/layout

In the following section, we discuss error-related findings from studies in health care environments, highlighting the above factors associated with errors and productivity, to identify implications for design. This discussion also includes a synthesis of articles that address environmental design’s role in staff safety and job performance.

Noise

Noise is one aspect of the environment that can negatively affect both staff and patients. Noise levels within the hospital are produced by staff, visitors, patients, and hospital devices, such as telephones, alarms on equipment, and the beeping of patient monitoring devices (Bayo, Garcia, & Garcia, 1995; Topf & Dillon, 1988). Ulrich et al. (2004; also Joseph & Ulrich, 2007) conducted an extensive review of literature on health care settings and physical environments. Their team identified more than 130 references that discussed noise in hospital settings. A majority of these dealt with the effect of noise on patients. Some of the studies, however, offer insight on the impact noise has on the nursing efficiency.

According to the World Health Organization guidelines, acceptable levels for continuous background noise in patient rooms are 35 dB. Nighttime peak noise levels should not exceed 40 dB (Berglund, Lindvall, & Schwela, 1999). Noise levels, however, increasingly exceed these recommended levels. Blomkvist, Eriksen, Theorell, Ulrich, and Rasmanis (2005), for instance, report that noise produced by medical equipment as well as staff reach 70 dB to 75 dB levels when measured at the patient’s head. Similarly, equipment such as x-ray machines produced noise levels exceeding 90 dB. Hodge and Thompson (1990) noted that peak sound levels recorded during surgery could interfere with the concentration of staff members, as well as prevent reliable communication among staff members.

Noise is problematic in a health care setting partially because there are a variety of sources of noise, many of which are loud (Ulrich, Lawson, &
Martinez, 2003 as cited in Ulrich et al., 2004). Sources of noise include telephones, staff voices, trolleys, and paging systems, among others. Another reason for high noise levels is that environmental surfaces reflect rather than absorb noise (Ulrich et al., 2004).

Room occupancy affects noise levels. Noise levels are lower in private rather than multi-occupancy rooms (Ulrich et al., 2004). Hilton (1985) conducted an empirical study \((N = 25)\) comparing three hospitals of various sizes. Noise levels were found to be lower in smaller hospitals compared to a larger hospital. Patients were relatively satisfied with noise levels, except for those who were in the recovery room of a large hospital. Single-occupancy rooms were also found to have lower noise levels than multiple-occupancy rooms. Similarly, Press Ganey (2003; as cited in Ulrich et al., 2004), who obtained data from 2,122,439 patients, noted that patients in private rooms were more satisfied with the noise levels in the room than patients in double-occupancy rooms.

**Staff outcomes: Health, safety, and job performance.** Noise levels are critical to creating an environment that is conducive to promoting staff health and safety. Bayo et al. (1995), in their study of 295 health care workers, determined that the main noise sources outside the hospital included road traffic, human voices, aircraft noise, and sirens. Noise sources within the hospital were produced by employees, patients, hospital devices, and visitors. Participants in this study felt that the majority of the noise produced was from within the hospital, and noise levels were found to be well above those suitable for a health care facility.

In their study of the impact of noise on burnout \((N = 100)\), Topf and Dillon (1988) found that disturbing noise levels promoted noise-induced stress, which in turn was associated with higher levels of burnout among critical care nurses. They found that the most disturbing noises were produced by telephones, alarms on equipment, and the beeping of patient monitoring devices. Furthermore, a greater degree of noise-induced stress was associated with higher levels of burnout among nurses. High noise levels, therefore, can negatively affect both patients and health care workers, thereby compromising patient care. Shepley and Davies (2003) compared noise levels between a rectangular design and a circular design. Though nurses walked less on the circular units, noise levels were not found to significantly differ between the two designs.

**Design implications.** Sound-attenuating surfaces can help reduce the amount of noise produced. Sound-absorbing ceiling tiles, single-bed rather
than multibed rooms, and the reduction of noise sources may help in noise reduction (Neumann & Ruga, 1995; Ulrich et al., 2004). Blomkvist et al. (2005) found that when sound-absorbing ceiling tiles replaced non–sound-absorbing tiles, patients slept better, reported lower levels of stress, and felt nurses provided better care. Similarly, carpeted hallways can keep noise to a minimum and having music available for patients can help reduce stress (Lowers, 1999; Neumann & Ruga, 1995; Weber, 1995). For instance, the introduction of a sound environment with specially designed music, staff members experienced reduced sound level in the ward as well a less stressful environment (Thorgaard et al., 2005). In addition, the majority of patients were satisfied with the music and experienced greater relaxation.

Suggestions to reduce noise levels include introducing music. As music has been demonstrated to reduce anxiety prior to and during surgery, Cabrera and Lee (2000) have suggested the use of a sound-control center to reduce noise levels as well as assist in reducing pain levels. Also, carpeted surfaces, sound-absorbing ceiling tiles, and sound-attenuating surfaces have been suggested to reduce noise levels (Lowers, 1999; Rollins, 2004; Shumaker & Reizemstein, 1982; Ulrich et al., 2004). The use of private rooms instead of multioccupancy rooms may also aid in reducing noise levels (Joseph & Ulrich, 2007; Ulrich et al., 2004).

Though most of the data reported on noise are based on the experience of patients, one may infer that staff members react similarly to noise levels. Excessive noise levels may result in physical effects, such as increased stress, among nurses, which could in turn affect their performance and errors. Within a noisy environment, people become less interpersonally engaged, cognition is impeded, and people tend to seek simple solutions to complex tasks (Grumet, 1993). Similarly, as noted earlier, excessive noise levels in the operating room were found to impair concentration and communication among staff members (Hodge & Thompson, 1990). This may be true on the general ward as well, which can impair the care given to patients and result in the occurrence of errors.

**Lighting**

Lighting quality, type (day light or artificial light), and level may affect patient as well as staff outcome.

*Staff outcomes: Health, safety, and job performance.* Nightingale (1859) noted that lighting is one critical element of the hospital environment. Exposure to daylight not only benefits patients, but it also has positive
effects on staff. As exposure to daylight increases, nurses are less likely to experience stress and dissatisfaction with their jobs, reducing their levels of burnout (Alimoglu & Donmez, 2005). Exposure to artificial lights, on the other hand, has a negative effect, as nurses find them to be very draining (Scott, 2004). It would appear, therefore, that nurses function more effectively in an environment with minimal artificial lighting and in an environment that facilitates the use of natural daylight.

Buchanan, Barker, Gibson, Jiang, and Pearson (1991) evaluated the impact of three different illumination levels on the dispensing errors of pharmacists. In general, errors were reduced when lighting levels were high. Medication error was 3.8% at illumination levels of 450 lx, whereas they decreased to 2.6% when illumination levels increased to 1,500 lx. Among staff \( (N = 730) \) in a redesigned hospital with greater lighting, the majority felt that the increase in natural light had a positive impact on their work life (Mroczek, Mikitarian, Vieira, & Rotarius, 2005). Even though windows produced glare, most employees still preferred to be located near a window. The inclusion of windows aids in buffering the effects of job stress and contributes to job satisfaction.

**Design implications.** To improve lighting, surfaces that reduce glare should be used, and patients should be exposed to natural daylight (Shumaker & Reizemstein, 1982; Weber, 1995). Indirect lighting diffuses light and assists in creating a natural effect (Lowers, 1999). Adequate lighting is necessary for a nurse to perform tasks required for patient care. In addition, as the average age of nurses is increasing, bright work surface illumination levels \( (1500-2000 \text{ lx}) \) may be necessary to reduce errors in dispensation and to aid in paper-based tasks (Ulrich & Barach, 2006).

**Ergonomics, Furniture, and Equipment**

Ergonomics is important to create the optimal working conditions for workers to perform their tasks efficiently and safely (Carayon, Alvarado, & Hundt, 2003).

**Staff outcomes: Health, safety, and job performance.** Staff perceptions of safety within the hospital influence the adoption of safe work practices (Gershon et al., 2000). Proactive approaches, in which nurses were made aware of activities that were most likely to lead to patient falls, led to a significant decrease in the number of falls (Brady et al., 1993). Yassi et al. (2004) reviewed compensation records of employees at eight facilities and
found physical workload and staffing levels were associated with time-loss injury rates, self-reported pain, burnout, health, and job satisfaction. Interestingly, employees at facilities with the lowest quartile time-loss injury rates had better staffing levels, fewer injuries, less pain, and better self-reported health.

Garg and Owen (1992) introduced ergonomic devices (e.g., walking belts, shower chairs, and hoists) in a nursing facility to determine whether these devices aided in reducing injuries among nursing assistants \((N = 92)\). Most assistants reacted positively to utilizing the devices and perceived physical stresses after introducing the devices were very low. In addition, fewer patient transfers occurred after introducing the devices, and there was a profound decrease in lost and restricted workdays among the employees. Hoists are particularly relevant, as the number of bariatric patients have grown in the hospitals. Appropriate devices and proper body mechanic are critical in reducing back pain and back injuries among staff.

Kroemer and Kroemer (2001) reviewed ergonomic elements of design; they recommended that nurses’ work stations should be designed to meet the requirement of nurses spending a significant time standing. For instance, sufficient space should be provided for the nurses’ feet to enable movement close to the counter. Carayon et al. (2003) stated that nurses are interested in communication links that have auditory, visual, or tactile components. Control links, such as access and use of a bedside computer, are also important. Finally, movement links, such as having the ability to survey a patient or the ability to control an apparatus by foot movements, might be critical in certain areas of the nursing unit. Hospital employees have many tasks that are physically demanding, and thus, they are prone to work-related musculoskeletal disorders (Janowitz et al., 2006). It has been reported that 92% of nurses working in geriatric settings have experienced an injury (Collins & Owen, 1996). Nurses \((N = 21)\) in an empirical study by Hui, Ng, Yeung, and Hui-Chan (2001) reported that turning, showering, and transferring patients were the most physically demanding tasks performed. Tasks with poor ergonomics are associated with higher absenteeism levels and may be related to lower levels of patient care (Janowitz et al., 2006). Poor ergonomics, then, may also result in increased errors among nurses.

With regards to equipment and technology, various attempts have been made to reduce medication errors. The installation of an automated computer-controlled device installed in nursing units (Medstation Rx) was associated with fewer medication errors (Borel & Rascati, 1995; Schwarz & Brodowy, 1995). The installation of Medstation Rx led to improvements in the administration of medication as scheduled (Shirley, 1999).
A drawback of Medstation Rx is line-up during busy times (Borel & Rascati, 1995). Medication errors, including ordering, transcription, and dispensing errors, decreased with the use of a computerized physician order-entry system (CPOE; Bates et al., 1998).

**Design implications.** To improve the way nurses handle patients, proper furniture and equipment are necessary. Beds, tables, trolleys, and wheelchairs, for instance, should be suitable, available, and maintained. Also, nurses should be properly trained on equipment usage, and storage should also be available and accessible. Furthermore, hoists and lifting aids were recommended among nurses (Hignett & Richardson, 1995).

Carayon et al.'s (2003) recommendations for the improvement of ergonomic design in health care facilities include maximization of visual and tactile discrimination through the use of the appropriate size, color, and texture of materials. To minimize decision time, for instance, they suggest that patient headboards have blood pressure cuffs and suction cups on both sides of the bed and that different alarm sounds be used, associating them with different medical devices. To optimize the nurses’ opportunity for movement, equipment in patient rooms should be located in an area that enables easy access. Finally, to minimize the need for human strength, they recommend the use of mechanical devices, such as beds that move from side to side or gurneys that enable a patient to have an X ray without being transferred to an x-ray table.

**Layout, Wayfinding, and Patient Room Design**

The built environment should be convenient and accessible and should enable patients to connect with staff members, should be conducive to the patients’ sense of well-being, should be safe and secure, and should foster connections to the outside world (Lowers, 1999).

**Staff outcomes: Health, safety, and job performance.** Access to space within the hospital affects nurses’ perceptions of their workplace. A study conducted by Halford and Leonard (2003) in two National Health Service Hospitals in England found that nurses had the least access to space among staff members within their hospitals. Their spatial confinement to their wards often led nurses to have a strong spatial identification with their ward while having negative feelings toward other spaces within the hospital. Through this lack of space and their sense of territoriality, their nursing identities are formed. In addition, a lack of space was associated with the
impression that the hospital did not care about its nurses and generated stress among nurses. Opportunities are also limited to relax and relieve themselves of their anxieties.

Specific types of nursing units affect job satisfaction and burnout. Sochalski (2001) noted that medical-surgical nurses, in comparison to nurses in other units, reported lower levels of quality of care, higher numbers of tasks left undone at the end of a shift, and high levels of emotional exhaustion. Furthermore, nurses working in acute medicine have higher levels of emotional exhaustion than nurses working in accident and emergency (Gillespie & Melby, 2003).

Single-occupancy rooms have also been associated with better communication among staff, reduced need for patient transfers, fewer medication errors, and decreased infection rates (Page, 2004). In a maternity ward, equipment and supplies were easier to access, privacy was greater and noise levels were reduced, and quality of care was also perceived as being greater because nurses were better able to respond to the emotional and physical needs of the patients (Janssen, Harris, Soolsma, Klein, & Seymour, 2001). St. Joseph’s Hospital in Wisconsin standardized the design of the patient care environment that helped to reduce their staff error (Reiling, 2004). “Standardization of patient care environments and equipment greatly decreases the cognitive load on the nurses, making routine tasks less likely to cause slips and lapses” (Carayon et al., 2003, p. 36). At Barbara Ann Karmanos Cancer Institute in Detroit, Michigan, medication rooms were expanded to reduce distraction for nurses from coworkers and focus more on the tasks at hand. In addition, countertop space was increased, supplies were better organized, undercabinet task lighting was installed, and acoustical panels were used to absorb noise. With this new design, error rates were decreased by 30% (Simmons, 2003).

Wayfinding is of particular importance because if patients or staff members have difficulties orienting themselves within the facility, they may become frustrated and disoriented, which in turn may lead to them experiencing stress (Carpman & Grant, 1993; Moeser, 1988). Furthermore, when a hospital is redesigned, the staff need to learn new routes to make their way around the facility, which can also lead to anxiety and stress (Christensen, 1979). If staff experience stress, absenteeism rates may increase and their ability to take care of patients may decline.

Single-occupancy rooms have been found to improve quality of care outcomes as well, when compared to multiple-occupancy rooms (Chaudhury, Mahmood, & Valente, 2005, 2006). Benefits of single-occupancy rooms include shortening a patient’s length of stay, a reduced risk of acquiring
a hospital born infection, and the reduced risk of medication errors (Anonymous, 2000). St. Joseph’s Community Hospital in West Bend, Wisconsin, incorporated failure modes and effects analysis (FMEA) to aid in the creation of a design in which patient safety was at the forefront. Safety-driven principles were developed to minimize the occurrence of serious adverse events such as patient falls and operative/postoperative complications. Some of these design principles include visibility of patients by staff members, automation where possible, immediate accessibility of information, and noise reduction (Reiling, 2004; Reiling et al., 2003). Key to the design of St. Joseph’s was the standardization of the patient room in terms of occupancy (single occupancy) layout, location of supplies, and equipment and furniture (in-room sink, charting alcoves with a window, supplies and computers available in the alcoves, carpeted floors, bedside computers, oversized windows, sitting areas, and a close proximity between the bed and bathroom) because standardization reduces the potential for error by making the environment less stressful (Reiling & Knutzen, 2003).

Acuity-adaptable rooms offer patients control of lighting, temperature, and privacy. These rooms are designed to enable a patient to receive all the care required in one room regardless of their acuity level. Acuity-adaptable rooms are larger in size than the regular patient room and facilities using this type of room have lower rates of medication errors, patient falls, phlebitis, and procedural and lab errors as well as shorter lengths of patient stay (Hill-Rom, 2002). The combination of acuity-adaptable rooms and decentralized nursing stations has resulted in improved clinical outcomes, cost-effectiveness, and operational efficiency, and patient and staff satisfaction (Hendrich, Fay, & Sorrells, 2002, 2004). Hendrich et al. found that patient transfers decreased by more than 90% on a unit with acuity adaptable rooms. In addition, overall patient days per bed have decreased because the patient is not required to move. These units have also been found to improve patient safety as patient falls and medication errors have decreased and patient satisfaction has increased. Similar results were obtained with universal rooms that enable patients to remain in the same room throughout their hospital stay. A reduction in patient transfers has led to reduced medication errors at Clarian Health Partners (Runy, 2004).

Barbara Ann Karmanos Cancer Institute has renovated areas within the hospital to be patient centered. Medical rooms were made larger and an emphasis was placed on lighting and acoustics. A decrease has occurred in the use of pain medication on these units as well as a decrease in medication errors (Bilchik, 2002). Infection control is also affected by design. Dettenkofer et al. (2004) reviewed 17 studies that looked at the impact of
design on infection control and found that higher number of beds on intensive care units was associated with higher incidences of infection. Having more patients on a ward increases infection rates and can prolong a patient’s stay (Kibbler, Quick, & O’Neill, 1998). McCarthy (2004) suggested that single rooms should replace multipatient rooms to increase patient privacy and reduce rate of nosocomial infections.

**Design implications.** Stichler (2001) offered some design guidelines with regards to health care facilities. He suggests that healing environments improve one’s connection with nature, culture, and people, and promote a positive self-awareness. Single-occupancy, and if possible, universal rooms and/or acuity-adaptable rooms can accommodate patients and family members as well as provide increased storage for equipment. Furthermore, a balance must be achieved between the need for staff to view patients and respect for the patients’ privacy. Furnishings used in the rooms and on the ward should be comfortable and durable. Barach and Dickerman (2006) noted that goals for designing a facility with regards to patient safety include reducing the risk of injury to both patients and staff, removing or minimizing hazards, and educating designers in the complexity of promoting safety within the health care environment.

Design recommendations to improve patient care by Spreckelmeyer (2004) included the use of a universal room, decentralized patient care; enhanced direct contact between patients and staff through room and unit design; the elimination of sensory distracters in areas where nurses perform detailed tasks; the use of automated, computerized medical records; patient social supports; incorporating elements of a natural environment; the need for personal control for each nurse; the need to provide communal spaces where information can be exchanged; and attention to ergonomic details.

**Focus Group Findings**

Three focus groups were conducted at three hospitals in the Pacific Northwest (Swedish Medical Center, Providence, St. Vincent Hospital and Providence, Portland Hospital) to specifically understand the potential role of the physical environment on medication errors. Methods for recruitment of and conducting the focus groups have been discussed earlier in the Method section. The following issues emerged as the key environmental design aspects related to medication errors.
Medication Dispensation

Medication room. The general consensus was that location of the medication room within the nursing unit is the most important criterion for reducing nurses’ fatigue and errors. The staff preferred multiple decentralized medications rooms within the floor, as opposed to central medication rooms. It was pointed out that decentralized medication rooms can save travel time and reduce potential for errors, as the nurses walk back and forth several times between the medication room and patient rooms. In the new tower at Providence Portland, recently conducted planning sessions concluded to provide decentralized medication rooms serving every eight patient rooms. This is hoped to reduce the walking time needed between medication room and the patient rooms substantially, and consequently, the potential for fatigue and errors.

Automated dispensation. With regards to the automated medication dispensation machine Pyxis, participants preferred the machine to be located in a closed versus an open area. This is because in an open area people stand in line and can block doorways. Other negative aspects of the Pyxis in an open area are the distractions and the noise levels. Also, space is unavailable to draw medications, and working space to look up the patient and drug is nonexistent. Without adequate workspace, nurses are handling too many things at once creating a potential for error.

Medication delivery. The handling of medication passes through various hands from the time it leaves the pharmacy until the medication reaches the patient; thus, there is potential for error at several points. In one facility, for instance, medications arrive in the nursing unit by one of two means. One manner in which they arrive is through a runner, who works out of the pharmacy. The runner loads medications onto a cart from the pharmacy and then drops off the medications in the back room where the Pyxis machine is located. In this scenario, oral medications as well as IV medications are grouped together, which becomes a problem, because nurses do not look for the oral medications among the IV medications. A second manner in which medications arrive to the nursing unit is through a tube system that is situated at the nursing station. This is problematic because the nurses’ station tends to be chaotic and any person, not necessarily a nurse, may retrieve the medication and misplace it. The medication should be placed in the Pyxis machine, but this is not always the case, and replacement orders are placed when the medication is not found.
Nursing unit design. It was noted that the pod design decreases fatigue among nurses and keeps nurses closer to their patients. Unit design is influenced by patient acuity. For instance, a circular nursing station was preferred among nurses on units with high-acuity patients. This design facilitates visibility, which is critical to the care of high-acuity patients. Open areas were preferred in intensive care units because even though noise is a factor, patients can be monitored from the nursing station. In general, nurses preferred unit layout in which they have a visual link to the patients, yet have audio privacy. Small alcoves within the nursing station were found to be beneficial, as nurses can communicate with other staff members regarding patients while still maintaining low noise levels within the nursing unit. Nursing units closed off with Plexiglas were also found to be beneficial due to high patient visibility with low levels of noise.

Computerized charting. Computerized charting was considered to have both positive and negative features. In general, nurses preferred computers mounted outside the patient room in the current design of their hospitals. However, lack of seating option was pointed out as difficult by a few staff members. In one facility, computers are mounted in the patient’s room requiring nurses to chart with their backs toward the patient. Patients complain that nurses are turned away from them. Also, nurses are constantly interrupted by patients who communicate with them while they are trying to complete their charting. Nurses prefer to be facing patients at eye level while charting, in particular if the computers are mounted in the patient rooms. As charting stations were kept outside the patient rooms in hallways, nurses complained of having to stand while charting in the patient rooms and preferred to chart while seated. Nurses enjoyed using computers-on-wheels (COWs) as this allows them the flexibility to move the computer within the room (and outside the room) as needed.

Patient rooms. Focus group participants overwhelmingly preferred single- over double-occupancy rooms. The main reasons for this preference were privacy, safety, and reduced errors. With regard to specific features in the room, nurses felt that accessibility to a sink, either outside or inside the patient room, is necessary. Bathrooms should be located so that it has the shortest distance for a patient to reach from the bed. Patients should not have to walk to the front of the bed where they can get tangled in their IV or oxygen lines. In terms of wall panels, it was found that horizontal wall panels are at one level, which enables nurses to see everything right away. Vertical wall panels, however, appear less clinical. Consistency among the
patient rooms received mixed support. Participants felt that consistency would reduce fatigue, inefficiencies, and errors. Consistency, however, was not thought to make any significant difference if all rooms are single occupancy.

Based on the focus group interviews, Table 2 summarizes the various spaces, associated activities, potential errors, physical environmental aspects, and recommended design issues.

**Recommended Design Principles to Reduce Conditions Producing Errors**

Integrating the major issues identified in the literature and the key findings from the empirical study, we propose the following design principles.

**Balance Between Patient Accessibility and Reduction of Disruptions**

Decentralized nurses’ stations can provide greater visibility and accessibility to the patient rooms. However, the trade-off is reduced communication/consultation between staff members. On the other hand, open-plan nurses’ stations (especially centralized ones) are highly problematic for interruptions and disruptions from various sources. There is no easy answer to the issue of advantages and disadvantages of centralized versus decentralized nurses’ stations. In terms of layout of the main nurses’ station, the key design aspect provides work spaces that allow flexibility in terms of visibility/accessibility to the patients and at the same time provide reduced interruptions from coworkers and noise disruptions. A combination of open-counter work spaces with adjacent small work rooms with doors is helpful in having the flexibility for staff to minimize interruptions as required by the tasks. Within the open-counter work area, a certain portion could be enclosed to reduce disruptions from noise and reduce interruptions, yet allowing visual connection with the hallways.

Accessibility of patient information at the bedside is helpful in reducing errors during order entry, data entry, and so on. Among the different locations of computer-based charting, the COW in the patient room allows flexibility in terms of direct data access and entry at the bedside. However, this (or charting just outside the patient room) does not provide seating for staff (lack of seating during charting was pointed out as a contributing factor in staff fatigue in this study). Therefore, a seated charting area within
<table>
<thead>
<tr>
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<td>Errors during interpretation/translation of orders from one document to another</td>
<td>Shelving of meds/IVs Lack of visibility Medication labeling errors</td>
<td>Shelves that allow greater visibility of the medication bins Demarcation of various work spaces to reduce interruptions and distractions Accessibility and privacy</td>
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<tr>
<td>Medication Room</td>
<td>Dispensation Preparation of Meds and IV Fluids</td>
<td>Dispensing errors Preparation errors</td>
<td>Multiple staff talking (distractions &amp; interruptions) Noisy Staff fatigue Lack of adequate counter space Adequate space for multiple activities (e.g., med. dispensation, preparation) Positive sensory stimulation through appropriate colors and other visual cues.</td>
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<tr>
<td></td>
<td>Spiking IV Fluids</td>
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<td>Pill Crushing</td>
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<td>Safety Checks</td>
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<tr>
<td>Clean Utility Room</td>
<td>Selecting supplies Pill crushing</td>
<td>Selecting incorrect supply Error in safety checks</td>
<td>Multiple staff talking (distractions &amp; interruptions) Noisy Lack of adequate counter space Adequate space for multiple activities Adequate counter space Reduced noise Adequate space for multiple activities</td>
<td>Adequate counter space Reduced noise Adequate space for multiple activities</td>
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<td></td>
<td>Pick up refrigerated bags</td>
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<td>Safety checks</td>
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<tr>
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<tr>
<td>Nurses’ Station</td>
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<td></td>
<td>Medication Administration Record</td>
<td>Errors in medication records</td>
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<tr>
<td></td>
<td>Faxing medication request</td>
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<tr>
<td></td>
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<td></td>
<td>Lack of visual access to patients</td>
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<tr>
<td>Patient Room</td>
<td>Administering Meds.</td>
<td>Medication administration errors</td>
<td>Accessibility to a sink</td>
<td>Individual patient medication supply system</td>
</tr>
<tr>
<td></td>
<td>Electronic charting</td>
<td>Errors in medication administration records</td>
<td>Patient Access to bathroom</td>
<td>Computerized Physician Ordering Entry system (CPOE)</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
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<td>Staff Fatigue</td>
<td>Distance and support for patients room bed to the</td>
<td>Sink visually accessible and adjacent to the entry</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>bathroom</td>
<td>Supported access to bathroom from bed</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Layout of power and respiratory outlets</td>
<td>Consistent layout and equipment may reduce fatigue, inefficiencies, and errors</td>
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<td></td>
<td></td>
<td></td>
<td>Lighting contributes to errors</td>
<td>Single-occupancy room for greater privacy and safety, and reduced error rates</td>
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</table>
the patient room or next to the patient will be helpful in reducing fatigue/stress during accessibility of information in close proximity to the patient.

**Automation**

Automation can substantially streamline the system of medication prescription, storage, dispensation, preparation, and administration. There are several areas where automation could reduce errors. Areas were automation are recommended and worth considering: computerized physician order entry allowing access to evidence-based practice at point of ordering, order verification, medication storage (*Pyxis* machine, refrigerator, other), dispensation, preparation, administration (bar coding), documentation of med effects, ordering of materials/supplies, movement of materials/supplies, and so on.

**Minimize Staff Fatigue**

*Noise reduction.* Noise reduction is a critical component in minimizing fatigue and stress among staff members. The specific design aspects in regard to noise reduction include nursing unit layout (number of beds, centralized vs. decentralized nurses’ station), type of flooring (carpeting, rubber or other flooring with appropriate sound absorption and maintenance parameters), single-patient rooms, sound insulation in walls between patient rooms, high sound-absorbing ceiling tiles, elimination of overhead paging system, reduced noise in telemetry alarm system, and timing of shift change.

*Decentralized medication rooms.* Decentralized medication rooms or individual patient medication cabinets can reduce the length and amount of walking necessary for nurses. Walking to and from patient rooms and medication room/nurses’ station is an important factor contributing to staff fatigue. Pods with 8-12 patient rooms having their own medication room can reduce walking-related fatigue as well as errors taking place in centralized medication room serving 30 or more patients. Medication rooms need ample work surface for medication preparation and other desk tasks by multiple staff members at the same time.

*Positive staff break room.* Rejuvenating staff break room is an overlooked issue in nursing unit design. A staff break room’s location needs to be close to the nursing unit, yet provide a distinctly calming atmosphere. Access to nature, either through views, incorporation of landscaping or
physical access to a garden can be a powerful method in providing staff a rejuvenating break time that can help reduce the negative effects of fatigue and stress of the nursing unit.

Promote a Culture of Safety

To develop a self-sustaining mechanism that will monitor, report, and act on nursing and medication errors, it is critical that there is an organizational culture of safety in place. At this point, most of the facilities have voluntary reporting of errors. This process needs to be emphasized by creating an active agenda for nonpunitive error reporting and identifying methods to prevent or minimize errors. Built-in mechanisms to track errors, possible errors, stress and fatigue, and the identification of possible environmental correlates will help maximize the benefits of positive environmental design features.

Conclusion

The conceptual framework of this review focused on the conditions in the environments that can lead to error-producing latent conditions. There is evidence regarding the negative impact on staff resulting in stress, anxiety, and distractions due to noise; artificial lighting; improper or inadequate ventilation; and disorienting layouts of nursing units. Also, there is literature on the pros and cons of various nursing unit configurations. Some of the key issues in nursing unit design in effecting staff fatigue and stress—potentially impacting errors are travel distance, patient visibility from nurses’ station and hallway, distribution of support space, flexibility, patient room design, and visual linkage with outdoors. Less information is available on the effect of different workspace design and environmental features, such as size and layout of nurses’ station, privacy, task lighting, visual access, access to support spaces, and so on. In addition, the impact of patient room issues, such as patient room configurations, layout of furniture and sink, relationship between the patient room vis-à-vis the nursing unit design, visual access from nurses’ station and hallways, and so on have not been addressed adequately in the empirical literature. Nurses’ efficiency, potential for errors, stress levels, and overall job satisfaction will be affected by a myriad of these design issues and their combinations.

Although there is scarce empirical evidence on the direct impact of the physical environment on errors, our study based on focus groups with staff
clearly reveal the importance of design on errors. These issues include decentralized medication room, computerized charting at or near the bedside, and single-patient rooms. Potential conflicts between various tasks such as privacy needed for charting and the opportunity for surveillance on patients stood out as highly relevant design issues in error-producing conditions. A participatory planning and design process involving the nursing staff at various levels of hierarchy might be helpful in understanding the real-life demands of the jobs and identifying environmental sources of stress, frustration, and conflicts. Finally, effective design needs to occur with organizational and regulatory commitment for flexibility in how nursing units are operated in terms of number of staff, staff training, and required communication patterns between staff, workload, and overall culture of safety in the workplace.

Notes

1. Databases searched: EBSCO, ABI/Inform, PsycINFO, Medline, Ageline, Web of Science, Social Science, Citation Index, EMBASE, Pubmed, Worldcat and JSTOR.

2. Following is a list of journals and trade magazines searched for relevant articles:

Nursing, Hospital, and Healthcare

Architecture and Design

Social, Psychological, and Behavioral Issues
Other


3. Institute of Medicine report “To Err is Human: Building a Safer Health System” is a landmark document in identifying patient safety issues, and it puts forward a policy agenda for reducing medical errors.

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