Executive Summary

It has been estimated that approximately 44,000 Americans die in hospitals each year as a result of preventable medical errors (Kohn et al., 2000a). The estimated national costs of adverse events in the United States is 37.6 billion dollars, while the national costs of preventable adverse events has been estimated to be 17 billion dollars (Kohn et al., 2000b). Physical environment is an important component in the acute care setting that can directly impact patient safety, nursing and medication errors, as well as contribute to staff fatigue, stress and burnout resulting in errors. However, there is no comprehensive review of the literature in this area; also, empirical studies linking the physical environment and errors in hospitals are very scarce.

This study examines this issue in the medical-surgical units with multiple methods that include:
• Literature Review and Analysis
• Survey on Nursing Staff in Four Hospitals in the Pacific Northwest
• Focus Groups with Nursing, Administration and Pharmacy Staff Members
• Site Visits to Three Selected Facilities that have implemented Design for Enhanced Patient Safety and Reduction of Errors

Highlights of the Literature Review and Analysis

In order to gain an understanding on the environmental factors related to nursing efficiency, nursing and medication errors and other outcomes, an extensive review of literature was conducted in the area of nursing and medication errors in healthcare environments and other work places, staff efficiency, staff safety, staff burnout and other staff outcomes, infection control and patient outcomes. The research questions that guided this review and analysis are:

1) What are the effects of environmental variables on nursing and medication errors, nurses' efficiency, and quality of patient care in medical-surgical nursing units?

Figure 1: Number of literature items reviewed and analyzed in the various substantive areas
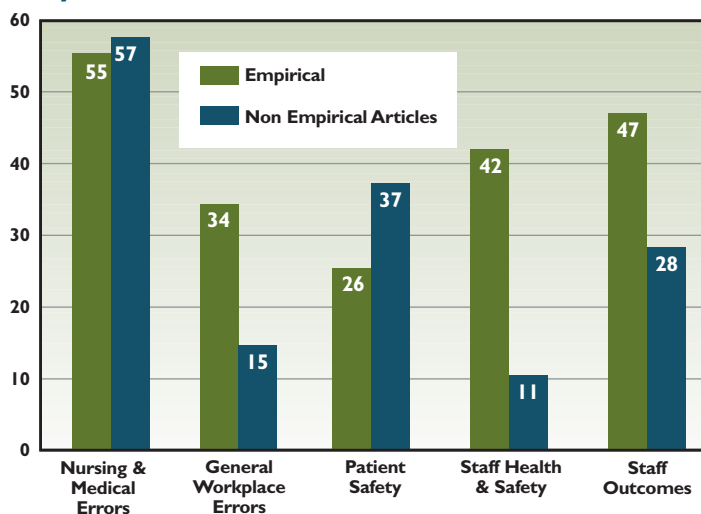
2) What are the effects of environmental variables on nurses' job satisfaction, health and safety in medical-surgical nursing units?

In total, 204 empirical (evidence-based) and 148 non-empirical (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. A breakdown of the reviewed items by substantive areas is provided in Figure 1.

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 healthcare staff work spaces within the hospital add to staff stress and may increase the risk of medical errors. Nursing errors and efficiency can be conceptualized at two levels, "active failures" and "latent conditions" (Reason, 2000). "Active failures" can be attributed to human cognition and limitations of memory and thought process. "Latent conditions" refer to failures resulting from decisions made by the management and architects. Examples include: physical environmental factors such as noise, lighting, color, temperature and layout and design and organizational factors such as time pressure, stress, fatigue, work overload, lack of privacy, etc. These issues highlight that the design of nurses' work environments (physical, organizational and social/psychological) need to be supportive of the nature of their work, and responsive to their particular needs.

To identify the environmental/architectural factors that affect nursing and medication errors, nurses' job performance/satisfaction, patient and staff safety, we reviewed and analyzed findings from the literature in the following four substantive areas:

i) Errors in the workplace (both healthcare and non-healthcare settings)

ii) Hospital design and environmental variables related to staff health and safety

iii) Hospital design and environmental variables related to patient safety

iv) Health care facility management, design and environmental variables related to staff outcomes – job satisfaction and effectiveness of nursing professionals.

In this executive summary, we highlight issues from the literature on error in the healthcare, as well as non-healthcare settings. Discussion on the other three sections is provided in the literature review document.

In acute care settings, errors often occurred in physician ordering and nursing administration. The most common medication errors are prescription/medication ordering errors, dispensing errors, errors in administration, and errors in the medication record. Dispensing errors are associated with a high prescription volume, being overworked, fatigue, interruptions, and drugs that look alike or sound alike (Hodgkinson, Koch, & Nay, 2006). The literature examining the effects of environmental variables on errors in acute care setting is limited. However, there have been some significant studies on error in non-healthcare work places and these have implications for healthcare settings. Though our focus was on environmental factors, we also reviewed some pertinent literature on non-environmental factors as environmental factors in combination with organizational and other factors lead to nursing, medication and other types of error in acute care settings. To get a broader contextual picture of why errors (especially latent error/failure) occur, we need to have an understanding of all the factors involved in the process.

EFFECT OF ENVIRONMENTAL DESIGN ON REDUCING NURSING AND MEDICATION ERRORS

Our review demonstrated that the following environmental variables contribute to work place errors:

- Noise levels
- Lighting
- Color
- Ergonomics/Furniture/ Equipment
- Heating, Ventilation and Air Conditioning
- Design/layout

The non-environmental variables associated with workplace errors include:

- Fatigue/long work hours
- Staffing levels
- Stress
- Faulty judgment
- Age of worker

Environmental Factors

Noise is Distracting and Disrupts Concentration, and is Highly Likely to Contribute Towards Error

The effects of noise on health outcomes, as well as work performance, are contingent upon several factors including the nature of the noise and the type of work task involved. There are two types of negative effect of noise on performance: 1) Effects of unpredictable noise are more severe on job performance than those of predictable noise, 2) Any negative effect of noise increases with task complexity (Leather, Beale & Sullivan, 2003). The interaction of unpredictable noise and high task complexity result in increased error in calculation, tracking and monitoring tasks, slower learning of new materials and poorer recall and memorization (Sundstrom, 1986). Loud, unexpected and unfamiliar noises may create a distraction, which could disrupt performance. When individuals are repeatedly distracted, overload may occur, which results in ignoring low-priority inputs. Noises may also block sounds which provide useful feedback, such as alarms on machines (Sundstrom, 1987).

Noise is problematic in a healthcare setting partially because there are a variety of sources of noise, many of which are loud (Ulrich, Lawson, & Martinez, 2003 as cited in Ulrich, Zimring, Quan, Joseph, & Choudhary, 2004). Sources of noise include telephones, staff voices, trolleys, and paging systems, among others. A higher degree of noise-induced stress was associated with higher levels of burnout for nurses (Topf & Dillon, 1988). Room occupancy affects noise levels. Noise levels are lower in private rather than multi-occupancy rooms (Ulrich et al., 2004).

These research findings on occupational noise highlights that one has to take into account the full context of each work setting (e.g., the type of work, type of noise, duration of noise, duration of work task, workers own health status, organizational factors etc.) to understand what type of effect noise may have on different groups of workers in that setting. Suggestions to improve the acoustics in a space include use of sound absorption materials like batts, acoustic panels, partition-

ing large spaces into smaller work spaces or partitioning off noisy areas, and creation of quiet areas with the work setting for specific tasks (Banbury & Berry, 2005). In healthcare settings, 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).

Inadequate Lighting (either too bright or too dark) Can Impede Task Performance

Performance of tasks which involve visual discrimination of details declines when lighting levels are not bright enough (Sundstrom & Sundstrom, 1986). Control over the degree of lighting helps individuals perform tasks more effectively (Ebben, 2001). Lighting levels can affect healthcare staff effectiveness in performing critical tasks. Higher lighting levels are recommended to reduce medication error (Buchanan et al., 1991). On the other hand, glare from excess light, wrongly directed light and reflective surfaces cause reduction in visibility and discomfort in the work settings (Abdou, 1997; Kroemer & Kroemer, 2001; Ruck, 1989a). Research and examples of work places where people are productive demonstrates that the incorporation of natural daylight helped increase worker performance (Abdou, 1997; Brill, Margulis, Konar & Bosti, 1984; Sundstrom, 1987). To improve lighting in healthcare settings, surfaces that reduce glare should be used, and patients and workers should be exposed to natural daylight (Mroczek, Mikitarian, Vietra, & Rotarius, 2005; Shumaker & Reizemstein, 1982; Weber, 1995). In addition, being as the average age of nurses is increasing, bright work surface illumination levels (1500-2000 lx) may be necessary to reduce errors in dispensation and to aid in paper-based tasks (Ulrich & Barach, 2006).

Different Color Schemes Invoke Certain Responses; If the Color Scheme is not Suited to the Task On Hand, Errors May Result

Color impacts mood, satisfaction, motivation, and performance (Stone, 2003). In particular, warm colors, such as red, focus people outward and increase their awareness and alertness regarding their environment. Cool colors, such as blue and green, focus people inward enabling them to focus on mental and visual tasks (Wineman, 1979).

Color affects an employee's accuracy. More errors were made in the white office than in the green or red offices. Working in the red office was associated with reduced confusion (Kwallek & Lewis, 1990). The color of the environment may affect the perceptions of other environmental factors. A noisy environment, therefore, may be perceived as less noisy in cooler colors such as blue or green, whereas noise levels may be exaggerated in a red or yellow environment (Tofle, Schwarz, & Max-Royale, 2004). Similar effects have been noted with regards to the temperature of the environment. Guidelines have been suggested with regards to color in healthcare facilities. Stimulating colors should be used in the recreation areas and lounges. Cool colors should be used to promote relaxation in quiet or secluded rooms (Mahnke, 1996). For sub-acute care and rehabilitation, Leibrock (2000) suggests that intense colors should be used for accents and contrast to improve visual organization. Malkin (1982, 1992) suggests that red and yellow colors should be used in a setting where creativity and socialization are desired. Green and blue colors should be used in areas that require concentration and visual acuity. Cool colors also promote less distraction and more opportunity to concentrate on difficult tasks, and may thus be beneficial to nurses.

Inadequate Workstation Design and Tasks with Poor Ergonomics are Associated with the Development of Musculoskeletal Disorders and Higher Absenteeism Levels, and May be Related to Lower Levels of Patient Care and Increased Error Rates

Common ailments, such as sciatica, hernia, arthritis, muscular tension, and fatigue, may originate following irregular motions and maintaining a certain posture for prolonged periods of time. Tasks with poor ergonomics are associated with higher absenteeism levels, and may result in reduction or poor quality patient care in acute care settings (Janowitz et al., in press). For workers who stand for long periods of time, such as nurses, a prolonged stationary posture may result in some of these ailments and affect their work performance (Franco & Fusetti, 2004). The design of their work environment should help to reduce some of these ailments. For instance, their workstation should be designed so that there is sufficient space for the nurses' feet to enable movement close to the counter (Kroemer & Kroemer, 2001).

Relationships between the components incorporated in the design are critical to efficiency. Nurses need communication links that combine auditory, visual, or tactile components. There are no empirical studies looking at the ergonomics, design, communication and equipment in patient care areas of hospitals. However, designers (and experts in this field) recommend control links that include access and use of a bedside computer, movement links in areas where nursing staff can survey a patient and have the option controlling an apparatus by foot movements at the same time (Carayon et al., 2003). Further, Carayon et al. (2003) offer various recommendations to improve ergonomic design in healthcare facilities. To minimize perception time, both visual and tactile discrimination should be maximized through the use of the appropriate size, color, and texture of materials. To minimize decision time, for instance, patient headboards could have blood pressure cuffs and suction cups on both sides of the bed and different alarm sounds could be associated with different medical devices. To optimize the nurses' opportunity for movement, the equipment should be located in an area which enables easy access. Finally, to minimize the need for human strength, the use of mechanical devices should be used, 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.

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. As well, nurses should be properly trained with regards to equipment usage and storage (Hignett & Richardson, 1995). With regards to equipment and technology, various attempts have been made to reduce medication errors. Computerized physician order entry can improve the efficiency of care on intensive care units and reduce medication errors. The installation of an automated computer controlled device stored directly on nursing units (Medstation Rx) was associated with fewer medication errors (Borel & Rascati, 1995; Schwarz & Brodowy, 1995).

Poor Ventilation Systems and Excessive Thermal Environments May Compromise an Individual's Health and Lead to Stress and Negative Task Performances

Ventilation is critical to the functioning of an acute care facility. Ulrich et al. (2004) suggest that adequate ventilation and its maintenance are necessary to ensure the safety of staff and patients. Existing studies (Lundstrom, Pugliese, Bartley, Cox, & Guthier, 2002; Menzies, Fanning, Yuan, &

EFFECT OF ENVIRONMENTAL DESIGN ON REDUCING NURSING AND MEDICATION ERRORS

FitzGerald, 2000) on ventilation in hospitals do not deal specifically with error; they do demonstrate that the health of nurses (and patients) is affected by ventilation. If their health is compromised, so might their ability to adequately care for their patients, which may result in increased errors.

Mental performance is associated with the temperature of the office. Mental performance deteriorates with higher room temperatures (25 degrees Celsius for people who are un-acclimatized to the environment and 30-35 degree C for those who are acclimatized) (Kroemer & Kroemer, 2001). Prolonged exposure to heat will result in reduced performance of tasks since arousal levels will fall to below normal levels, distraction levels increase, and muscular activity becomes impaired (Sundstrom, 1987; Sundstrom & Sundstrom, 1986)

Productivity increases when workgroups are kept small and well-integrated, sources of distraction are kept to a minimum, and the design of the work setting is comfortable, safe, and healthy (Leaman & Bordass, 2000). Personal control over environmental variables also aids in improving an individual's performance and job satisfaction (Leaman & Bordass, 2000; Lee & Brand, 2005).

Single-Occupancy Rooms Can Reduce Errors

Single-occupancy rooms have also been associated with better communication among staff, reduced need for patient transfers, fewer medication errors, and decreased infection rates (Chaudhury et al., 2006; Page, 2004). Quality of care was also perceived as being greater since nurses were better able to respond to the emotional and physical needs of the patients (Janssen, Harris, Soolsma, Klein, & Seymour, 2001).

Non-environmental/Organizational Variables

Working Long Hours Contributes to Fatigue, Resulting in Slowed Reaction Time, Reduced Attention to Detail, Compromised Problem Solving, and Errors of Omission

Shift-work affects an individual's ability to sleep. Shift workers in non-healthcare (e.g., air traffic controllers) settings were found to sleep more, feel greater confusion, fatigue, and decreased vigor when working night shifts (Luna, French & Mitcha, 1997).

Working long hours has detrimental effects on patient care. Error rates were found to be three times higher when nurses worked shifts lasting 12.5 hours or more (Rogers, Hwang, Scott, Aiken & Dinges, 2004).

Negative effects of fatigue include slowed reaction time, reduced attention to detail, compromised problem solving, and errors of omission (Institute of Medicine, 2004; Krueger, 1994; Page, 2004). People working shift work (especially night shift) report impaired job performance, administration error, sleep disturbances, fatigue, and a greater likelihood of injuries (e.g., needle stick injuries) and accidents, incorrect operation of medical equipment, increased errors, in particular drug administration errors, due to sleepiness (Krueger, 1994; Page, 2004; Suzuki, Ohida, Kaneita, Yokoyama, & Uchiyama, 2005).

Stressors in the Work Environment Include Time Pressures, Deadline Pressures, an Uneven Distribution of Resources, and a Heavy Work Volume

Errors caused by work overload, faulty judgment, and a stressful experience led to a lack of confidence and increased anxiety in nurses (Meurier, Vincent & Palmer, 1997). Some negative effects of stress include anxiety, depression, increased blood pressure, reduced immune function, and sleeplessness (Barach & Dickerman, 2006). Stress healthcare workers experience is associated with the constricted use of common-sense solutions to safety, the widespread use of beginners in their field including residents and interns, the fact that little has been done to reduce sources of human error, and the shift of clinical care to an ambulatory setting (Amalberti, Auroy, Berwick & Barach 2005). Job rotation and job sharing can help reduce one's exposure to a high stress job for long periods of time.

More Errors Occur When Staffing Levels are Insufficient and Due to Faulty Judgement

Staffing levels are associated with the occurrence of adverse events. Research has demonstrated a relationship between low staffing levels and a higher number of medication errors and wound infections occurrence (Hall, Doran, & Pink, 2004). Patient falls are also more likely to occur when staff levels are low (Whitman, Kim, Davidson, Wolf, & Wang, 2002; Unruh, 2003; Yang, 2003). Lack of knowledge regarding the use of drugs as well as incomplete, illegible, or verbal prescriptions can also lead to errors (Leape, Bates, Cullen, Cooper, Demeacao, Gallivan, et al., 1995; Tissot, Cornette, Demoly, Jacquet, Barale, & Capellier, 1999).

Leadership Amongst Those in Authority, as well as the Implementation of an Error Reporting System, Can Reduce the Occurrence of Errors

Successes in other industries, such as chemical, material manufacturing, and defense, have demonstrated that reporting errors has improved safety. Systems of error reporting enable both staff members and those in leadership positions to learn from the mistakes and help prevent future similar errors from occurring. Healthcare is a "system that is highly complex and tightly interrelated" (Barach & Dickerman, 2006). The safety profile of an organization, including healthcare, is measured by "reporting on the number of adverse events over a time interval" (Amalberti, Auroy, Berwick, & Barach, 2005, p. 757). One of the main barriers in improving patient safety is the lack of awareness amongst those in healthcare regarding the extent to which errors occur daily in acute care facilities (Kohn, Corrigan, & Donaldson, 2000). Unfortunately, people working in healthcare have been afraid of reporting errors due to fear of reprimand and fear of losing the respect of colleagues (Paparella, 2005). Furthermore, when dealing with errors, healthcare professionals tend to look at individual patients rather than the system itself. Attention should be shifted to the system to prevent all patients from receiving inadequate service (Barach & Moss, 2001).

Various strategies have been suggested to reduce the occurrence of errors (Benner, Sheets, Uris, Malloch, Schwed, & Jamison, 2002; Hodgkinson, Koch, Nay, & Nichols, 2006; Kohn et al., 2000; McClanahan, Goodwin, & Houser, 2000):

• One method is to reduce people's reliance on their memory. Recollection from memory regarding tasks that need to be performed and than manner in which they are performed is

flawed. Through the use of protocols and checklists, people are able to use aids when making decisions, thus reducing the potential for error

- A second strategy to reduce errors is to improve access to information. Healthcare professionals should have access to patient information, including medications and therapies, at the point of care. This can be achieved by having pharmacists available on nursing units as well as placing lab reports at the patient's bedside, among other approaches.

- A third strategy which can improve patient care is the use of error-proof processes

- Standardizing tasks is another method through which errors can be reduced. By implementing routine processes, people are able to familiarize themselves with the manner in which a task should be performed. The practice gained at performing tasks in a routing manner will help reduce opportunities for errors.

- A final strategy which can aid in error reduction is reducing the number of hand-offs that occur. By eliminating numerous transfers of material and information, the potential for error decreases

Leadership is an administrative aspect which is critical to error prevention (Leape & Berwick, 2000). Patient safety should be a central focus for corporate leaders. This includes evaluating the hospital design as well as incorporating safety goals among the corporate business plans (Kohn et al., 2000). Accidents often occur through a combination of human error and through faulty systems. By correcting system design failures, the institution is creating an environment in which patient safety is central (Kohn et al., 2000).

Tables 1-4 in Appendix A provide a summary of the key variables, issues and references related to error in acute care and general work settings. It includes empirical (evidence-based) and nonempirical (expert opinion and anecdotal information) articles for both environmental and non-environmental variables (in both healthcare and non-healthcare settings) and uses a 'star' system to denote the quality and quantity of articles/chapters in each area with higher number of stars indicating more articles and research has been conducted in a particular area. Additionally, Table 2 in Appendix B provides a summary of the various activities, errors and design aspects associated with the different spaces in a medical-surgical nursing unit.

Summary of Empirical Study

The empirical portion of the study was divided in to three sections:

a) Survey with Nursing Staff

We conducted a cross-sectional survey with nursing staff members. The sampling frame for this study included nurses working in four hospitals in Pacific Northwest region of the United States: Providence Portland, Providence St. Vincent (Portland), Providence Newburg (Oregon), and Swedish Hospital (Seattle). The sample comprised of 84 nurses. Questionnaires administered to nursing staff focused on nursing unit design, the medication room, errors and adverse events, job performance and satisfaction, and demographic information. The questionnaire is included in Appendix F.

b) Focus Groups with Key Personnel Addressing Design and Error Issues

Focus groups interviews were conducted at three facilities: Swedish Hospital, Providence Portland, and Providence St. Vincent. Staff members from these hospitals, including nurse managers, pharmacists, administrative personnel and risk managers participated in these focus groups. Discussions centered on facility design, medication administration, and causes of errors. The results from the focus group sessions are included in the study narrative section. It follows the results from the survey. The focus group discussion guide is provided in Appendix G.

c) Site Visits to Acute Care Settings that have Incorporated Design Features to Enhance Patient Safety and Reduction of Errors

Three hospitals that have been noted in literature as implementing environmental changes to improve patient safety and reduce error were selected for the site visits. These hospitals are: Bronson Methodist Hospital, Barbara Ann Karmanos Cancer Center, and St. Joseph's Hospital. Interviews were conducted with key staff members of these hospitals. These interviews focused on facility design and its impact on patient safety and errors. Additionally, the environmental changes were photographically documented. Summary of the facility visit interviews is also included in the study narrative section. It follows the focus group findings.

Summary of Results from Survey with Nursing Staff in Selected Hospitals in Oregon and Washington

Nursing Units and Stations

Most nurses in this study worked in units with centralized nursing stations. Environmental characteristics that were noted as *helpful* in nursing units (in their facilities) included:

- Hand washing and disinfection locations and protocols[1]
- Storage space for dirty supplies
- The location of the medication room
- Medication dispensation method (automated system)

Environmental factors noted as *neither helpful nor problematic* included furniture type and arrangement, lighting and location of storage rooms. Environmental factors identified as *problematic* (especially in their own hospitals) included:

- Space for clean supplies
- Availability of space in the charting area
- Patient surveillance opportunity
- Noise levels in patient care unit
- Privacy in the nursing stations

- Nursing station layout
- Walking distances to patient rooms
- The size of the medication room
- Heating and cooling systems
- Visibility to all areas of the nursing unit

Many of these issues (e.g., noise, layout, walking distance, patient surveillance opportunity, etc.) were identified as important environmental elements in literature (see literature review section).

EFFECT OF ENVIRONMENTAL DESIGN ON REDUCING NURSING AND MEDICATION ERRORS

Medication Room and Errors

The majority of participants preferred a central location of the medication room close to the nursing station and where happy with the location of medication room if it was centrally located in their particular nursing unit. Some problems identified for medication rooms were: inappropriate location as it was too far away from most functions in the unit, lack of space or very limited space.

All hospitals studied had automatic medication dispensation systems. The main benefits of an automated system were as follows: there is less chance of an error occurring, they are more efficient, tracking of medications and users, readily available meds, no narcotic counts, better organization, and it being safer for patients. Some drawbacks noted included waiting times (i.e., waiting in queue to get the medication), medications not being there when needed and a slow response time when ordering medication. Overall, most participants felt that the automated medication dispensation method has somewhat reduced medication errors in their hospitals.

The study participants stated that most types of medication errors rarely occurred in their units. Some of these (rarely occurring) errors include IV medication rates being too slow or too fast, the wrong concentration or dosage of medication delivered in the IV, the wrong route of administration, wrong medication administration, and wrong medication delivered due to the misidentification of a patient. The nurses noted some environmental factors that contribute to these errors (though they cautioned us that this was not a common phenomenon):

- The location of the med. room
- Problematic organization of medical supplies
- Poor lighting in the med. room.
- Inadequate size of the med. room
- High levels of noise

Some non-environmental factors noted include unreadable or missing medication labels, medication not being documented, lack of supplies and calculation errors.

Correlations for Medication Errors

Individual correlations were conducted between the frequency of medication errors and factors contributing to medication errors to determine if any significant relationships existed. One has to interpret these results keeping in mind that the sample size was very small (N=84) and the observations by the nursing staff were in context of their own work sites. Additionally, errors occurring due to environmental factors were rare.

- *For the error of missed doses of medication*, significant relationships were found with the following environmental factors: Problematic organization of medical supplies, high level of noise and poor lighting in the medication room.

- *Wrong time of medication administration* was associated with several environmental factors including location and inadequate size of medication room.

- *Medication errors of having the IV medication rate going too slow or too fast, having the wrong concentration of medication delivered in the IV, wrong route of medication administration, and wrong medication administration* were significantly associated with the following environmental

EFFECT OF ENVIRONMENTAL DESIGN ON REDUCING NURSING AND MEDICATION ERRORS

factors: location and inadequate size of medication room, poor lighting and high noise and problematic organization of medical supplies.

- *Similarly, having the wrong medication delivered due to misidentification of the patient* was significantly associated with all but one of the above factor, which was the location of the medication room.

Some additional correlations were run between physical environmental issues and errors:

- *Nursing unit design* was significantly associated with the frequency of medication errors and factors contributing to medication errors.

- *Staff and organizational issues leading to nursing errors* were significantly associated with physical environmental issues leading to nursing errors. (see the narrative section of the survey more detailed information and tables on these correlations).

Documentation Errors

The participants stated that documentation errors occurred rarely in their unit. Some infrequently occurring errors include documenting in the wrong patient chart and charting procedures or medications before they were completed. Though environmental factors did not commonly contribute to documentation error, on rare occasions some environmental factors that contribute to these errors include:

- Location of the charting space
- Poor lighting
- *Correlations for documentation errors*

- Small or inadequate size of the charting space
- High levels of noise

The points mentioned in medication error section about sample size and data holds true for the interpretation of these correlations too. Individual correlations were conducted to determine if an association existed between the frequency of documentation errors and environmental factors contributing to documentation errors. All documentation errors (mentioned above) were significantly associated with location of charting space, small or inadequate size of charting space, poor lighting and high level of noise

Nursing Errors

Various environmental factors are seen as very important causes leading to nursing errors. These include:

- Lack of privacy in the nurses' work area
- Inappropriate space layout in the nursing unit
- Insufficient space for documentation for charting
- Lack of space in the medication room
- High noise levels
- Faulty medication dispensation equipment
- Problematic location of the nursing station

EFFECT OF ENVIRONMENTAL DESIGN ON REDUCING NURSING AND MEDICATION ERRORS

Inappropriate location of the medication room was not seen as very important by some participants, but was seen as somewhat important by other participants. Inadequate lighting in the medication room also received mixed results. Inadequate lighting in the nursing station, faulty ventilation systems, non ergonomic furniture, and inadequate break room were not seen as problematic and the study participants did not think they contributed to nursing errors.

The study participants noted some non-environmental variables that lead to nursing errors and these included poor training of health professionals, overwork and stress of health professionals, high nurse to patient ratio, health professionals not working together as a team, poor handwriting by health professionals and lack of computerized medical records. One has to keep in mind that the hospital staff in focus group interviews noted that the non-environmental factors as more frequent causes of error than environmental factors, though they noted that environmental factors should not be overlooked.

Ranking of Environmental and Non-Environmental Solutions that Contributes to Reduction of Error

Ranking of Environmental Solutions (ranking of 1 to 5, with 1 being the best solution)

- Appropriate medication dispensation equipment (First)
- Sufficient space for documentation for charting (First)
- Reduced noise levels in the nursing unit (Second & Fifth)
- Appropriate location of the medication room (Second & Fifth)
- Adequate privacy in the work space (Second & Fifth)
- Appropriate lighting in the nursing station (Third)
- Adequate space in the medication room (Third)
- Appropriate location of nursing station (Fourth and Fifth)
- Ergonomic furniture, provision of break room for staff, adequate lighting in med. room, appropriate layout in nursing unit, appropriate HVAC system and floor (all ranked Fifth)

Ranking of Solutions to Staff and Organizational Issues

The *number one* solution was increasing the number of nurses per unit. Better training of health professionals was also among the top solutions as it was ranked *first* by 17 participants and ranked *second* by 18 participants. Reducing the number of work hours of nurses and using automated medication dispensation systems were both ranked *third* by a large number of participants. More use of computers instead of paper records for drug orders and medical tests was ranked both *third* and *fifth*. Also ranking *fifth* was more use of computerized medical records and requiring hospitals to develop systems to avoid medical errors.

Job Performance and Satisfaction

For the most part, participants stated that the physical working conditions help a great deal in affecting the manner in which they perform their job. In terms of job stress, most participants somewhat agreed when asked if they felt emotionally drained from work, felt used up at the end

of the workday and felt tired when getting up in the morning to face another day on the job. They disagreed with all the other stress and burnout options (see survey narrative section for all the options).

On a positive note, participants agreed when asked if they can effectively solve the problems that arise from work, if they effectively contribute to what the hospital does, and if they feel confident that they are effective at getting things done. Participants also agreed when asked about feeling good at their job, feeling exhilarated when accomplishing something at work and having accomplished many worthwhile things in their job.

Correlations Between Job Stress and Error

Correlations were run between job stress and variables pertaining to medication errors to determine if any significant relationships exist. The points mentioned in medication error section about sample size and data holds true for the interpretation of these correlations too. For each of the following variables, an overall average score was calculated and used. None of the correlations were significant. The variables used for correlations were as follows: the frequency of medication errors, the factors contributing to medication errors, staff and organizational issues causing medication errors, environmental issues causing medication errors, and nursing unit design.

Recommended Design Principles to Reduce Nursing and Medical 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' station can provide greater visibility and accessibility to the patient rooms. However, the tradeoff 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 vs. decentralized nurses' stations. In terms of layout of the main nurses' station, the key design aspect provide work spaces that allow flexibility in terms of visibility/accessibility to the patients and at the same time provide reduced interruptions from co-workers 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 necessary by the tasks. Within the open-counter work area, certain portion could be enclosed to reduce disruptions from noise and reduce interruptions, but allowing visual connection with the hallways.

Accessibility of patient information at the bedside is helpful in reducing errors during order entry, data entry, etc. Among the different locations of computer-based charting, the computer-on-wheels 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 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.

Standardization

Standardization of layouts/structure, equipments and procedures can potentially reduce nursing and medication errors, increase efficiency and avoid delays.

Patient room: identical bed orientation, location and design of sink, faucets, hand sanitizers, location and design of storage cabinet, windows (location, number and size), location of electrical and gas outlets, location of lights, type of lighting, bed controls, call lights, furniture, family sleeping arrangement.

Patient bathroom: arrangement, dimensions, non-slip protection areas, sinks, showers, toilets, emergency call lights.

Nurses' Station: Layout, arrangement of equipments, accessibility to patient rooms, and furniture.

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 (CPOE) 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, etc.

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 absorbent 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 own medication room can reduce walking related fatigue as well as errors taking place in centralized medication room serving 30+ 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. Staff break room's location needs 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 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

In order to develop as self-sustaining mechanism that will monitor, report and act upon 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 non-punitive error reporting and identifying methods to prevent or minimize errors. Built-in mechanism to track errors, possible errors, stress and fatigue, and identification of possible environmental correlates will help maximize the benefits of positive environmental design features.

Interview with Principal Investigators

Click here to play a 4:43 minute audio interview with the principal investigators. If the link does not play automatically, you will need to open through a media player such as Windows Media Player, Quick Time, or RealPlayer.

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[1] The percentage and frequency of participants for each category is provided in the report in the empirical study results. All tables and figures related to the data are also included in that document.