



 THE CENTER FOR HEALTH DESIGN® Research Coalition

PHASE I REPORT

HEALTHCARE ENVIRONMENTAL TERMS AND OUTCOME MEASURES: AN EVIDENCE-BASED DESIGN GLOSSARY

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I. INTRODUCTION

Background

Research into the impact of the healthcare environment on healthcare outcomes has been growing rapidly in recent years. Many scientific studies have collected empirical evidence demonstrating connections between the environmental design of healthcare facilities and outcomes that are important for patients, families, healthcare staff, and healthcare organizations (Ulrich et al., 2008). As a result, there is a growing understanding that an appropriately designed built environment can help to improve patient outcomes; create a safe, nurturing, and positive work environment for caregivers; and help achieve organizational and business objectives.

A key issue increasingly restricting the development and application of evidence-based design (EBD) research is the lack of a standard glossary of terms, definitions, metrics, and measurement tools that are commonly accepted by interdisciplinary design team members including researchers, designers, administrators, clinicians, and other stakeholders. This results in:

- A lack of generalizability in healthcare design research studies
- Difficulty translating research findings into design knowledge
- Difficulty developing a centralized evidence base for design
- Inefficient communication between stakeholders
- Difficulty benchmarking or comparing multiple facilities and conducting multi-site studies
- Difficulty making informed predictions based on research findings

To further promote the development, translation, and use of research about the built environment and its impact on healthcare outcomes, The Center for Health Design (CHD) initiated a project in October 2009 to develop a standard glossary of key environmental terms and healthcare outcome measures.

Purpose of this project

Phase I of this glossary project identified variables and metrics found in EBD research that examined relationships between environmental elements and healthcare outcomes in seven high-priority topic areas:

- Healthcare-associated infections (HAIs)
- Medical errors
- Patient falls
- Patient satisfaction
- Patient waiting
- Staff efficiency
- Staff satisfaction

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II. METHODS

The glossary project was conducted in several steps. Each step focused on one or two of the seven high-priority topic areas.

Advisory committee

An advisory committee consisting of six academic and industry experts from CHD's Research Coalition provided guidance throughout the project. The committee regularly conducted telephone conferences, reviewed results for each topic area, and provided suggestions and comments, including recommendations for additional environmental features and articles to be included in the project's literature analysis.

Literature search

An extensive search and review of research publications was conducted in each of the seven high-priority topic areas. The search focused on articles that: empirically revealed connections between physical environment variables such as ventilation rate and targeted healthcare outcomes such as infection rate; and were published in peer-reviewed journals in relevant disciplines such as medicine, nursing, healthcare service, management, architecture, and planning.

The literature search was conducted using several methods:

- Relevant articles from CHD's previous work were examined. This included two extensive reviews of EBD research literature conducted in 2004 and 2008, led by Ulrich and colleagues; and a research project focusing on the effects of sustainable design, sponsored by the U.S. Green Building Council.
- Research databases such as PubMed and EBSCO were searched for articles published after CHD's literature reviews.
- Additional relevant articles were found through references in the existing articles and through recommendations of advisory committee members.

Literature analysis

The top priority of the literature review was to identify all physical environment variables that have been found to impact targeted healthcare outcomes (e.g., HAIs) and to examine how these variables and outcomes were defined and measured in the existing research. Therefore, although multiple research articles were available for one environmental variable in many cases, articles were selected for detailed analysis based on the number and variety of metrics and measurement tools used in the research.

Information extracted from each article included definitions (when available) of the environmental variable(s) and outcome(s), measurement tool(s), sample size(s), setting(s), research design, and research findings. The extracted information was compiled into an article analysis table. The relationships that were studied between environmental variables, intermediate environmental quality variables, and outcome variables were illustrated using a topic model framework and a relationship matrix. Definitions and metrics used in the literature for each environmental variable or outcome measure were compiled into a glossary table and cross-referenced to the relevant topics.



III. RESULTS

Fifty environmental variables (Table 1) were found to impact 35 outcomes (Table 2) in the seven high-priority topic areas. Several environmental variables influence multiple outcomes in different topic areas, as shown in Table 1.

Table 1 Environmental variables in the seven high-priority topic areas

	HAls	Medical errors	Patient falls	Patient satisfaction	Patient waiting	Staff efficiency	Staff satisfaction
Acoustic ceiling tile				X			
Acuity-adaptable room		X		X			X
Air pressure difference between adjacent spaces	X						
Alcohol-based hand rub	X						
Amenities				X	X		
Antimicrobial-finished textile product	X						
Attractiveness, physical environment				X	X		X
Barcode-assisted dispensing system		X					
Bed alarms, medical vigilance system			X				
Bedrail and other physical restraints			X				
Bedside assortment picking (BAP) trolley		X					
Computerized physician order entry (CPOE)		X					
Computerized (automatic) reminder of hand hygiene	X						
Copper-silver ionization system	X						
Daylight		X					X
Distraction		X					
Emergency department layout					X		
Falls, multifaceted environmental intervention			X				
Hand hygiene devices, number of	X						
Head-mounted display						X	

Table 1 Environmental variables in the seven high-priority topic areas (continued)

	HAI	Medical errors	Patient falls	Patient satisfaction	Patient waiting	Staff efficiency	Staff satisfaction
High-efficiency particulate air (HEPA) filter	X						
HEPA filters, location of	X						
Illumination level (illuminance)		X				X	
Information access					X		
Interior finish material	X		X				
Interruption		X					
Laminar air flow	X						
Light fixture (luminaire)		X					
Medication distribution system						X	
Mobile air-treatment unit	X						
Music				X		X	
Noise		X	X	X		X	X
Nursing station layout			X			X	
Nursing unit shape/layout						X	
Patient bathroom design			X				
Patient room layout			X			X	
Patient room occupancy	X			X		X	X
Pharmacy equipment						X	
Physical configuration of drug stock shelves		X					
Physical proximity	X						
Positive distractions				X	X		
Rapid assessment clinic/pod/zone					X		
Subfloor			X				
Surface cleaning	X						
Ultraviolet germicidal irradiation	X						
Ventilation grilles, location of	X						
Ventilation, natural	X						
Ventilation rate	X						
Wireless technology						X	
Workroom layout						X	

Table 2 Outcomes in the seven topic areas							
	HAIIs	Medical errors	Patient falls	Patient satisfaction	Patient waiting	Staff efficiency	Staff satisfaction
Adverse drug event (ADE)		X					
Anxiety				X			
Bacterial growth	X						
Bioaerosol concentration	X						
Burnout							X
Circadian misalignment						X	
Cleaning, thoroughness of terminal cleaning	X						
Endotoxin concentration	X						
Fall-related injuries			X				
Falls, patient			X				
Hand hygiene compliance	X						
Job satisfaction							X
Length of stay	X						
Medication administration procedural failure		X					
Medication errors		X					
Medication processing time						X	
Mortality	X						
Nosocomial infections	X						
Nurse response to patient call						X	
Particulate level	X						
Patient colonization	X						
Patient loyalty				X			
Perception of physical environment							X
Satisfaction, patient				X	X		
Staff travel						X	
Stress, staff							X
Surface contamination	X						
Surgeon/anesthesiologist performance						X	
Surgical errors		X					
Team communication						X	

Table 2 Outcomes in the seven topic areas (continued)

	HAI	Medical errors	Patient falls	Patient satisfaction	Patient waiting	Staff efficiency	Staff satisfaction
Transport, intra-hospital patient transport		X					
Tuberculin conversion and reactivity	X						
Turnover intent							X
Waiting behavior, patient					X		
Waiting time, patient					X		

Detailed findings for each high-priority topic area are presented in three tables and one model/framework:

- An article analysis table including environmental and outcome variables, metrics, measurement tools, settings, study design, and other details extracted from each article
- A glossary table summarizing the environmental and outcome variables, definitions, metrics, and measurement tools in each topic area
- A matrix illustrating the connections between environmental variables and outcome variables
- A model/framework illustrating the relationships between environmental variables, intermediate environmental quality variables, and outcome variables

The *Results* chapter is organized into seven sections, each focusing on one high-priority topic area. Each section includes a summary of key research findings for that topic and a model/framework depicting the topic's environmental variables, intermediate environmental quality variables, outcome variables, and the studied relationships between these variables. The article analysis tables, glossary tables, and matrices are included in the *Appendix* which can be found at: <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>.

A. Healthcare-associated Infections

The environmental variables impacting HAIs can be grouped according to the major routes of infection transmission—air, inanimate surfaces, water, and the hands of staff

members (Figure 1). Studies show that reducing the contamination of air, inanimate surfaces, and water as well as improving hand hygiene influences the prevalence rate of HAIs and related outcomes.

Environmental variables impacting air hygiene can be classified into two categories—air flow design and air disinfection. Significant air flow design variables include patient room occupancy (single room versus open unit), location of ventilation grilles, ventilation rate, laminar air flow, air pressure difference between adjacent spaces, and environmental factors impacting natural ventilation (Beggs, Kerr, Noakes, Hathway, & Sleight, 2008; Gardner, Court, Brocklebank, Downham, & Weightman, 1973; Hutton, Stead, Cauthen, Bloch, & Ewing, 1990; Jiang et al., 2003; Menzies, Fanning, Yuan, & Fitzgerald, 2000).

One computational fluid dynamics study found that placing ventilation grilles on ceilings resulted in faster reduction of bioaerosol concentration than placing the grilles on walls (Beggs et al., 2008). Another study found that air flowing from a positive-pressure room where a patient had a large tuberculous abscess contributed to higher risk of tuberculin conversion in healthcare workers and reactivity in visitors and patients in adjacent areas (Hutton, Stead, Cauthen, Bloch, & Ewing, 1990). The size of operable windows, as measured by the ratio of window area to room volume, was negatively associated with infection rates of severe acute respiratory syndrome (Jiang et al., 2003).

Environmental strategies for air disinfection include high-efficiency particulate air (HEPA) filters, mobile air-treatment units using nonthermal-plasma reactors, ultraviolet germicidal irradiation (UVGI), ventilation system maintenance, and control of construction work (Barnes & Rogers, 1989; Bergeron, Reboux, Poirot, & Laudinet, 2007; Lutz, Rinaldi, Wickes, Huycke, & Mark, 2003; McDevitt, Milton, Rudnick, & First, 2008).

Crimi and others (2006) examined how the location of HEPA filters in the HVAC system significantly influenced air contamination level. Microbiological surveillance data showed that air contamination level was lower in hospital departments with HEPA filters placed at the openings of air ducts (peripheral) versus inside main air ducts (central).

Environmental factors influencing the contamination of inanimate surfaces include interior finish materials such as flooring and furniture surfaces as well as surface cleaning methods (Anderson, Mackel, Stoler, & Mallison, 1982; Lankford, Collins, Youngberg, Rooney, Warren, & Noskin, 2006).

Anderson and colleagues (1982) conducted an experiment in two patient rooms—one with carpet and one with bare vinyl flooring—and reported higher surface contamination on the carpet. Harris et al., (2010) examined bacterial community composition on carpet and vinyl flooring and found a lower number of genera but higher numbers of bacterial genus/species associated with genera of pathogenic bacteria on vinyl samples. Lankford et al., (2006) reported higher vancomycin-resistant enterococci (VRE) growth on vinyl composition tile, microvented perforated vinyl wallcovering, and paper-backed wallcovering than on other materials including synthetic or vinyl-backed carpet. Noskin and colleagues (2000) reported that disinfection with a quaternary ammonium germicide successfully removed VRE from vinyl furniture covering but not from fabric covering.

Hand hygiene is an important approach to preventing HAIs. Hand hygiene compliance can be improved by installing more hand hygiene devices, using alcohol-based hand rub dispensers, and utilizing automatic computerized reminder systems (Cohen, Saiman, Cimiotti, & Larson, 2003; Kaplan & McGuckin, 1986; Swoboda, Earsing, Strauss, Lane, & Lipsett, 2004).

In a comparison of two neonatal intensive care units (NICUs) with different handwashing devices, Cohen and colleagues (2003) found that staff hand hygiene was better in the unit with alcohol-based hand rub dispensers than in the unit with antimicrobial soap and sinks. Kaplan & McGuckin (1986) reported that staff hand hygiene compliance was higher in an intensive care unit (ICU) with a bed-to-sink ratio of 1:1 than in an ICU with a bed-to-sink ratio of 4:1. A team led by Swoboda (2004) evaluated the effectiveness of a computerized reminding system that gave prerecorded audio/visual messages instructing staff to wash their hands. The team found that the installation of this system resulted in significant increases in hand hygiene compliance and reduction of infections.

The water transmission of pathogens may be interrupted by a water disinfection system using copper-silver ionization. Modol et al., (2007)

found that the installation of the copper-silver ionization system significantly reduced water colonization of *L. pneumophila* and reduced the infection rate of hospital-acquired Legionnaires' disease from 2.45 to 0.18 cases per 1,000 patient discharges.

The vast majority of the above-mentioned environmental variables were measured on a categorical scale, such as single- versus multiple-occupancy rooms, central versus peripheral ventilation grilles, and alcohol-based hand rub dispensers versus water/soap sinks. Some environmental variables were measured on an interval/ratio scale. For example, ventilation rate was measured by air changes per hour or cubic feet per minute, and one metric of the relative number of hand hygiene devices was bed-to-sink/dispenser ratio. In most cases, environmental variables were manipulated by designers or researchers and treated as independent variables. Other methods of measuring environmental variables included site inspection and the tracer gas concentration decay technique for measuring ventilation rate.

Two groups of outcomes have been examined in literature:

- Healthcare hygiene such as the contamination of environmental surfaces, bioaerosol concentration, and hand hygiene compliance
- Healthcare outcomes such as infection rate, colonization, and length of stay

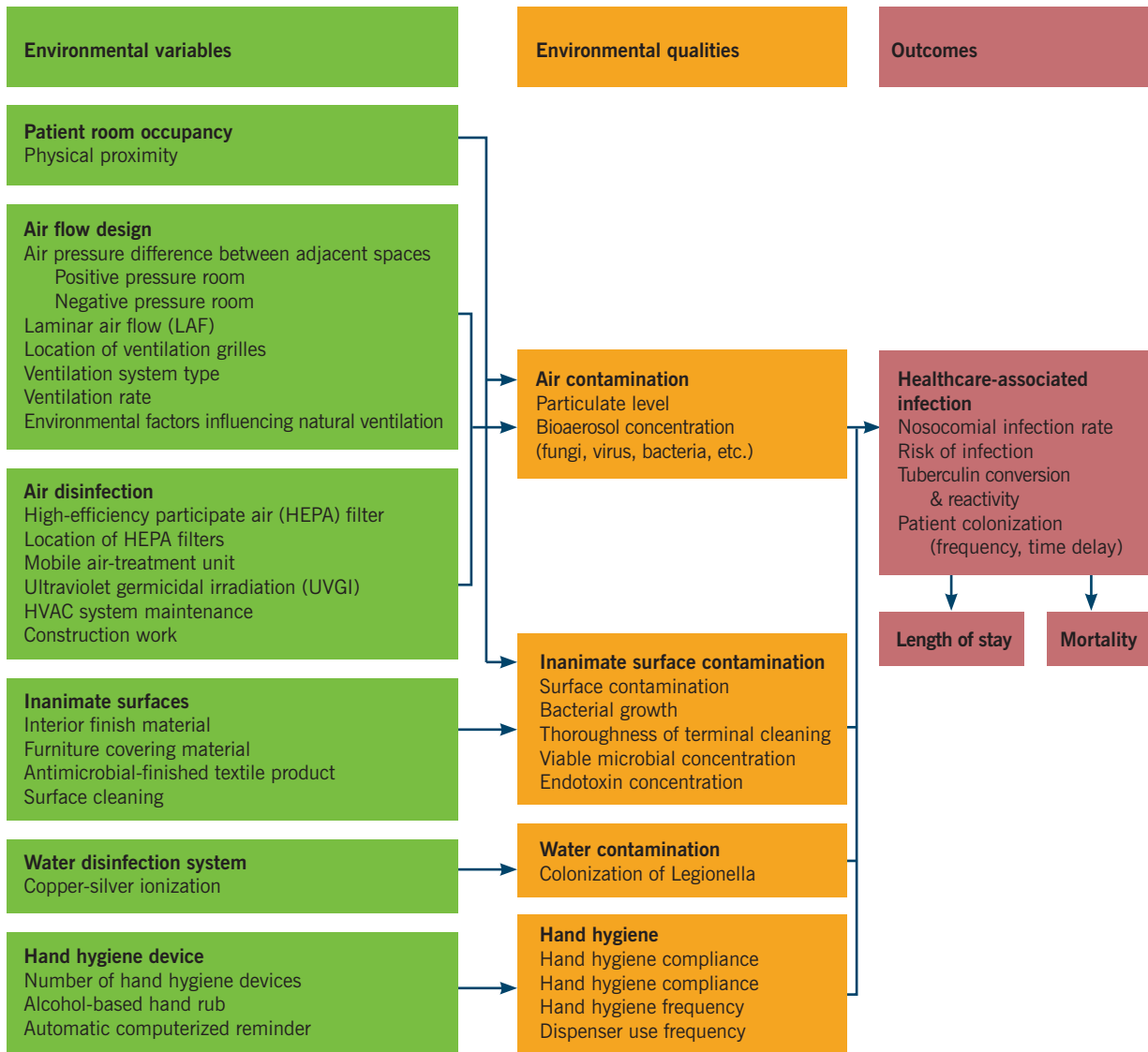
All outcomes were typically measured on an interval/ratio scale. Measurement tools included:

- Air sampling using particle counter or biocollector
- Surface culture
- Biology analysis
- Generic analysis (denaturing gradient gel electrophoresis)
- Fluorescent marker
- Behavior observation
- Automatic electronic system

- Microbiology surveillance
- Tuberculosis (TB) skin test
- Medical charts
- Estimation using established models/equations

For details, see the glossary table in the HAIs topic area, in the Appendix at <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>.

FIGURE 1
Model of environmental variables examined in relationship to HAIs



B. Medical Errors

Research has found that the design of the physical environment can impact two groups of medical errors—medication errors and surgical errors (Figure 2).

Environmental variables impacting medication errors include lighting fixtures, measures to reduce distractions and interruptions, acoustic design, use of acuity-adaptable rooms, and infrastructures for barcode-assisted dispensing and computerized physician order entry (CPOE) systems.

By manipulating lighting fixtures, Buchanan and colleagues (1991) evaluated the performance of pharmacists under three illumination levels – 45, 102, and 146 foot candles (ftc) – and found significantly fewer medication dispensing errors at higher illumination levels (146 versus 45 ftc). Length of daylight exposure had a positive correlation to nurses' medication administration errors in Alaska (Booker & Roseman, 1995). Distractions and interruptions caused by noise and unrelated traffic near pharmacists' work areas were associated with higher numbers of dispensing errors (Flynn et al., 1999). Physical separation and distance between items on drug stock storage shelves tended to help reduce medication dispensing errors in pharmacies (Flynn, Dorris, Holman, Garnahan, & Barker, 2002). Renovating and combining a critical care unit and a step-down unit into one, acuity-adaptable unit led to significant reductions in patient transfers and medication errors (Hendrich, Fay, & Sorrells, 2004). A dedicated medication repackaging center in the pharmacy and a bedside assortment picking trolley were among physical environment features supporting the implementation of a barcode-assisted dispensing system and CPOE, both of which significantly reduced dispensing errors (Poon et al., 2006).

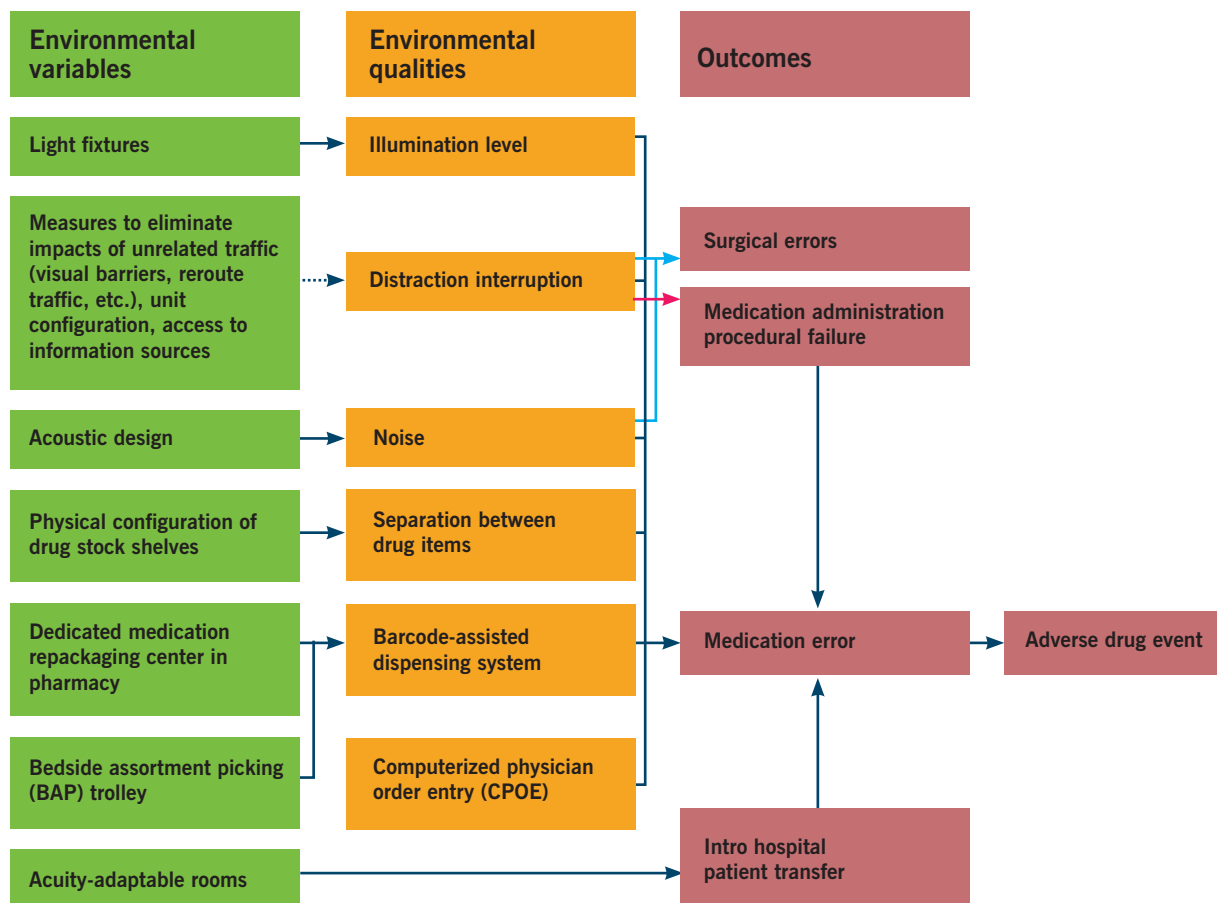
Environmental factors impacting surgical errors include distractions and noise. A simulated experiment showed that surgeons tended to make more errors while performing surgical tasks when exposed to auditory distractions such as popular songs and social conversation irrelevant to the surgical tasks (Plyuter, Buzink, Rutkowski, & Jakimowicz, 2010). Another experiment suggested that reducing the operating room's background noise level might help reduce surgical errors (Moorthy, Munz, Dosis, Bann, & Darzi, 2003).

Environmental interventions are typically manipulated and measured on a categorical scale such as yes or no. Other environmental variables are measured

on an interval/ratio scale. For example, lighting level is typically measured by a photometer; noise level, by a sound meter or dosimeter; distractions and interruptions, by direct observation and video-recording.

The two main metrics of medical errors include prevalence (e.g., dispensing errors per pharmacist per hour) and severity (e.g., minor versus major errors). The two major methods of measuring medication errors are direct observation with expert evaluation and use of existing data from adverse event reporting systems. The direct observation method is more frequently used. Surgical errors are mainly measured by a surgery simulation system.

FIGURE 2
Model of environmental variables examined in relationship to medical errors



C. Patient Falls

Environmental interventions aiming at reducing patient falls were often studied as one component of comprehensive patient fall prevention programs. Such programs typically included additional interventions such as training, education, physical exercise, and policy and operational changes.

Becker et al., (2003) evaluated environmental hazards contributing to patient falls and implemented a fall-prevention program that included modifications to lighting, chair and bed height, floor surfaces, room clutter, and grab bars. The program also included staff training, patient education, physical exercise, and protection. The patient fall rate decreased after the program's implementation. However, environmental interventions could not be disentangled from other interventions, making it difficult to estimate the contributions of the environmental interventions.

Environmental factors impacting patient falls can be grouped into two categories—environmental hazards that directly impact patients and factors that impact staff's ability to monitor patients and provide assistance (Figure 3).

Fall-related environmental hazards include physical restraints such as bedrails, hard flooring and sub-flooring, noise, shared bathrooms, limited opening area for bathroom doors, and other factors. Capezuti, Strumpf, Evans, Grisso, and Maislin (1998) reported that the removal of physical restraints such as vests, wrist/ankle restraints, and belts resulted in lower rates of falls and fall-related injuries. Healey (1994) found that patients who fell on vinyl flooring received more injuries than patients who fell on carpets. Simpson, Lamb, Roberts, Gardner, and Evans (2004) found that the rate of fall-related hip fractures was lower for falls on a wooden sub-floor than for falls on a concrete sub-floor.

A recently completed multi-site correlational study conducted by Calkins, Biddle, and Biesan (2011) identified multiple environmental factors impacting patient fall rates: bathroom design (e.g., private versus shared, amount of space between the opening side of the bathroom door and the closest wall or other obstacles, toilet location, grab bars around toilet), patient room layout (e.g., bathroom located at the headwall), flooring (e.g., size of flooring pattern, flooring material), and noise (e.g., alarms, overhead paging).

Design strategies that enhance staff's ability to monitor patients and provide assistance for the purpose of fall prevention include family space in patient rooms, medical vigilance systems, and decentralized nursing stations.

Renovating a nursing unit from a centralized nursing station with semi-private rooms to decentralized nursing stations with family spaces in single rooms reduced patient falls from 4 or more falls per 100 patient days to 2 falls per patient days (Hendrich et al., 2004). Designated family space in patient rooms was an independent factor contributing to lower rate of patient falls (Calkins et al., 2011). A medical vigilance system in which sensors on patient beds connected to a nursing call system to alarm nurses when patients left their beds, was also effective in preventing patient falls (Spetz, Jacobs, & Hatler, 2007).

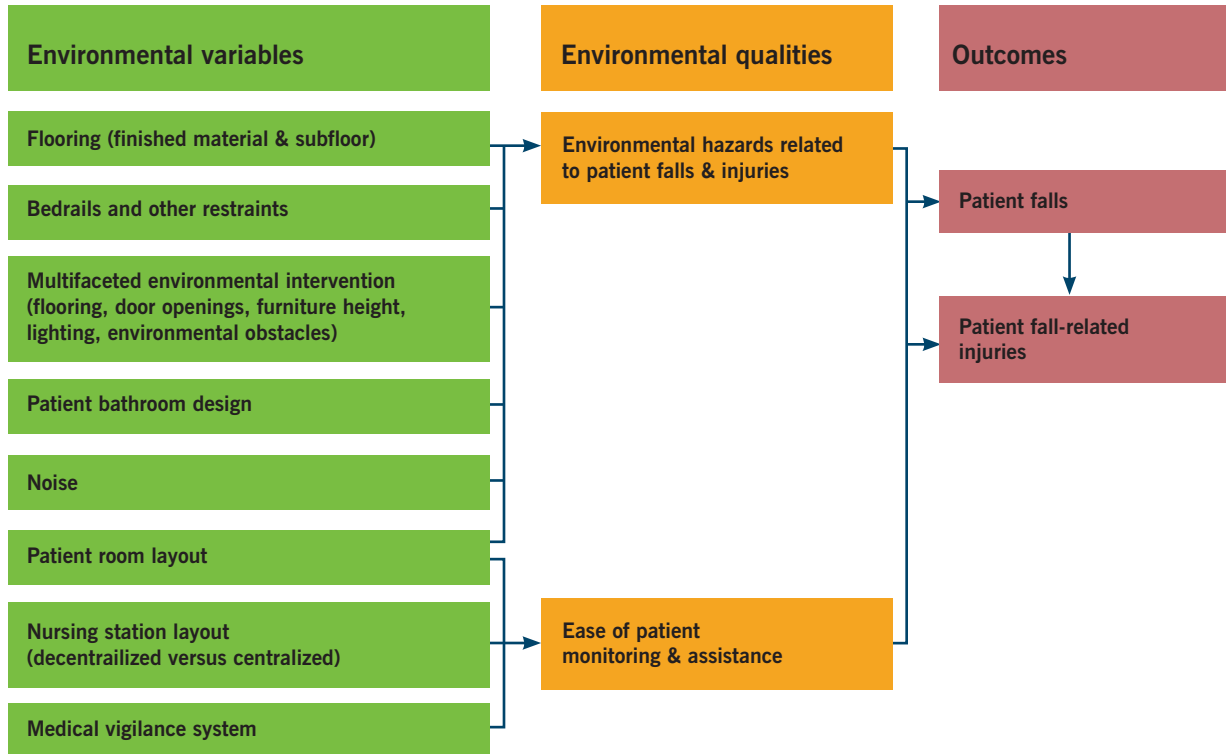
Environmental variables related to patient falls are typically categorical variables, for example, the type of flooring materials (carpet versus vinyl), or the type of nursing station layout (decentralized versus centralized). Three methods are used to measure environmental variables in observational studies: inspection or audit of the existing physical environment, data collected from existing incidence/accident reports, and direct observation of the usage of environmental features (e.g., use of physical restraints).

In interventional studies, environmental variables are typically manipulated by researchers, designers, or administrators. The major outcomes of these studies are patient falls and fall-related injuries. Currently, there are no universally accepted definitions, metrics, or measurement tools for these outcomes. Both outcomes can be measured by prevalence (e.g., number of falls or injuries per 1,000 patient days) and severity (e.g., percentage of falls resulting in injuries of different severity levels, number of hip fractures per 100 falls).

The measurement of falls and fall-related injuries has been highly dependent on incidence/accident reporting systems used by individual healthcare facilities. Different facilities use different systems, and self-reporting by staff is often biased. The lack of a universally accepted measurement system threatens the validity and generalizability of research.

FIGURE 3

Model of environmental variables examined in relationship to patient falls



D. Patient Satisfaction

Environmental variables impacting patient satisfaction can be classified into two main groups – factors related to patients’ physical comfort and factors related to aesthetic qualities of the physical environment (Figure 4).

Variables influencing patients’ physical comfort include noise reduction measures, room occupancy (number of beds in one room), acuity-adaptable rooms, unit layout, and amenities. Single-bed patient rooms scored higher than double-bed and multi-bed rooms in terms of patient satisfaction with admissions, hospital environment, information, overall quality of care, and other aspects of healthcare services (Harris, Shepley, & White, 2006; Nguyen Thi, Briancon, Empereur, & Guillemin, 2002). A comparison of double-bed rooms and multi-bed rooms showed that patients staying in double rooms were more satisfied than patients in multi-bed rooms (Soufi et al., 2010).

Hendrich and others (2004) reported a significant decrease in patient dissatisfaction after a building renovation combined separate critical care and step-down units into

one acuity-adaptable unit. Hagerman and colleagues (2005) found that patients were more satisfied with the overall quality of care and staff attitude after sound-reflecting ceiling tiles were replaced with sound-absorbing tiles that reduced noise.

Some before-after studies examined the effects of combined environmental factors on patient satisfaction. Patient satisfaction was significantly higher in a new unit with separated pods of patient bays, decentralized work stations, wireless communication, patient controlled lighting, windows, and a television for each patient than in an old unit with limited privacy, noise, no windows, harsh lighting, and a centralized nursing station (Smykowski, 2008). Patients were more satisfied with a new unit featuring single rooms, spaces for families and visitors, and wireless communication than an old unit lacking these features (Kline et al., 2007).

Within the group of environmental factors related to aesthetic qualities of the physical environment, attractiveness of the physical environment is an important predictor of patients' overall satisfaction with healthcare service. Higher attractiveness rating scores were associated with higher overall satisfaction in both outpatient and inpatient settings (Becker & Douglass, 2008; Swan, Richardson, & Hutton, 2003).

Specific factors in this group include positive audio distractions such as music; positive visual distractions such as nature views and artwork; lighting; furniture; and finish materials. Women who listened to relaxing music while undergoing a Cesarean delivery reported greater satisfaction with the experience (Chang & Chen, 2005). A new clinic waiting area with separated sub-areas, soothing music, nature views, and warm wall colors and lighting was associated with higher patient satisfaction than the old waiting area which featured one big room and "hospital-like" colors (Groff, Carlson, Tsang, & Potter, 2008). Patients were more satisfied with a waiting room environment incorporating healing features such as wooden chairs, nature photography, and indoor plants than with a traditional waiting room featuring elements such as plastic-covered chairs and small dried flower arrangements (Leather, Beale, Santos, Watts, & Lee, 2003).

The majority of environmental variables found for patient satisfaction were design or experimental interventions manipulated by designers or researchers. The interventions included positive distractions, acoustic ceiling tiles, acuity-adaptable rooms, and amenities.

Other environmental variables were measured using different methods. Patient room occupancy was measured using existing data from medical and administrative databases. Noise was measured by sound measurement equipment.

Subjective rating tools were used for rating physical environment attractiveness and patient perception of the physical environment.

Outcomes were measured by a variety of questionnaires/scales. Samples of patient satisfaction questionnaires/scales, including section titles and actual questions, were listed and compared. Patient satisfaction was found to refer to various aspects of healthcare, including physical environment, nurse, physician, overall experience, access/admission, discharge, food, family/visitor, cost, and overall quality. Another finding was that satisfaction surveys used in a research study might only cover a subset of the various aspects of healthcare. Therefore, patient satisfaction scores in different studies may not be fully comparable.

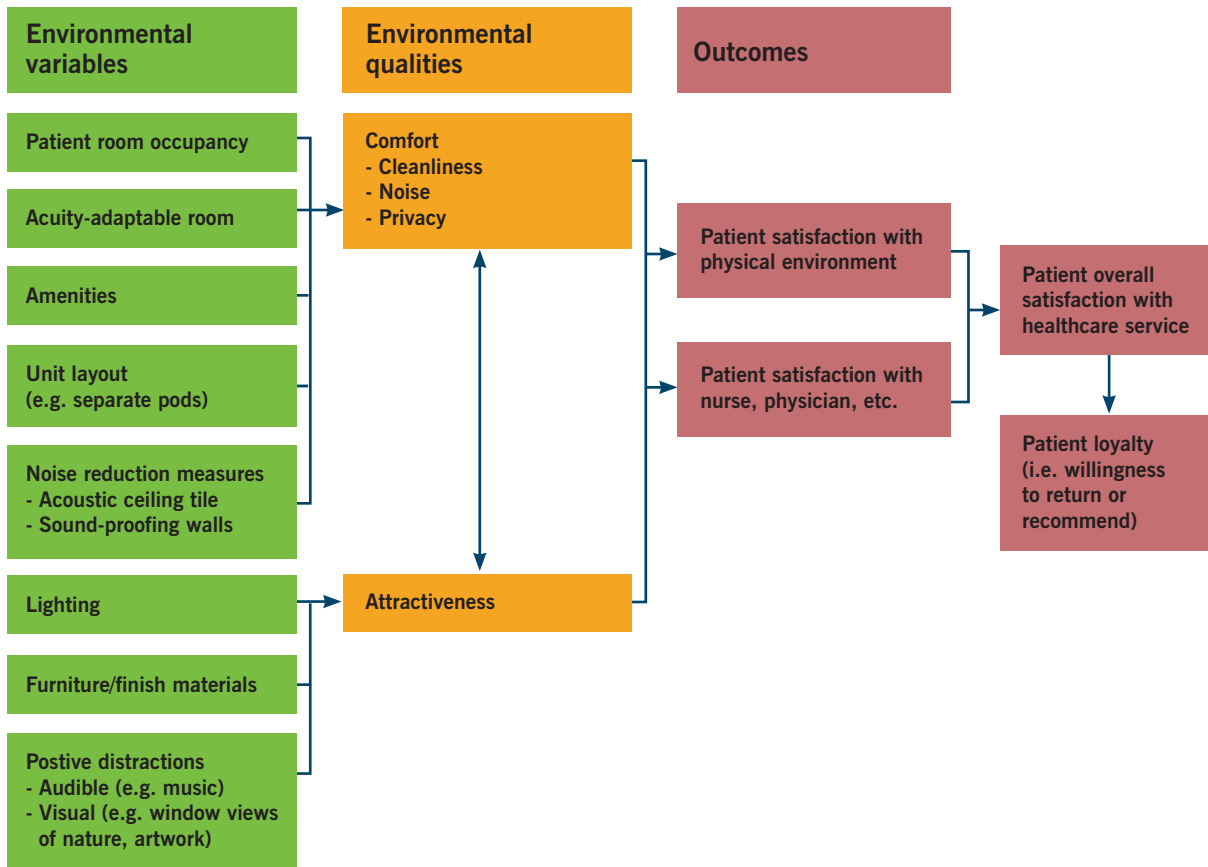
Two major scoring methods used in patient satisfaction are:

- Summation or average of scores of items in the scale or subscales (Groff et al., 2008)
- Count or percentage of the most favorable answer (e.g., “excellent” response in Becker & Douglass, 2008)

Patient satisfaction refers to a patient’s perception about past experience. Patient loyalty indicates the likelihood of a patient using the service again or recommending the service in the future. Another closely related variable in patient satisfaction literature is patient anxiety which is typically measured by standard anxiety scales (e.g., Spielberger State-Trait Anxiety Inventory [S-STAI] score).

FIGURE 4

Model of environmental variables examined in relationship to patient satisfaction



E. Patient Waiting

Environmental variables such as emergency department (ED) layout and the presence of a rapid assessment clinic or pod have been found to impact actual patient waiting time (Figure 5).

An ED rapid assessment clinic or pod (RAC or RAP) refers to ED spaces that accommodate stretchers for clinician assessment and procedures as well as chairs for patients who will be transferred to receive medications, IV therapy, observation, or who are waiting for results. Both environments are suitable for quick clinician assessment and procedures on patients whose dispositions do not require prolonged assessment or decision-making.

In one study, waiting time to be seen by a doctor was reduced 8 to 11 minutes and length of ED stay was reduced 20 to 25 minutes after an RAC was implemented (Ardagh, Wells, Cooper, Lyons, Patterson, & O'Donovan, 2002). In another study, the RAP helped reduce time from triage to bed by 24 minutes (Bullard, Lo, Latoszek, Holroyd, Rowe, 2008). In yet another study, patient waiting time in the ED treatment room was influenced by ED layout. Patients in a treatment room that was farther from the physician work station and had a solid door instead of soft curtains tended to wait longer (Hall, Kyriacou, Handler, & Adams, 2008).

Several environmental factors impact a patient's cognitive perception of waiting time, patient waiting experience, and waiting behaviors. Patients who periodically received information regarding ED process and medical procedures on devices such as TVs perceived significantly shorter ED stays and were more satisfied (Papa et al., 2008; Tran, Schutte, Muelleman, & Wadman, 2002).

Research has examined the possible connection between physical environment attractiveness and a patient's perceived waiting time but did not find any significant direct relationship (Becker & Douglass, 2008; Pruyn & Smidts, 1998). Environmental attractiveness was associated with more favorable perceptions of the quality of care, a higher percentage of anxiety reduction, and higher ratings of staff interactions (Becker & Douglass, 2008; Pruyn & Smidts, 1998). Positive distractions such as visual-audio stimuli presented on a plasma TV, nature photographs on canvas, window films with garden scenes, and cloud patterns attracted patients' attention during waiting time, significantly reduced patients' restless behavior and "people watching", and helped calm children (Nanda, 2010; Pati & Nanda, 2011).

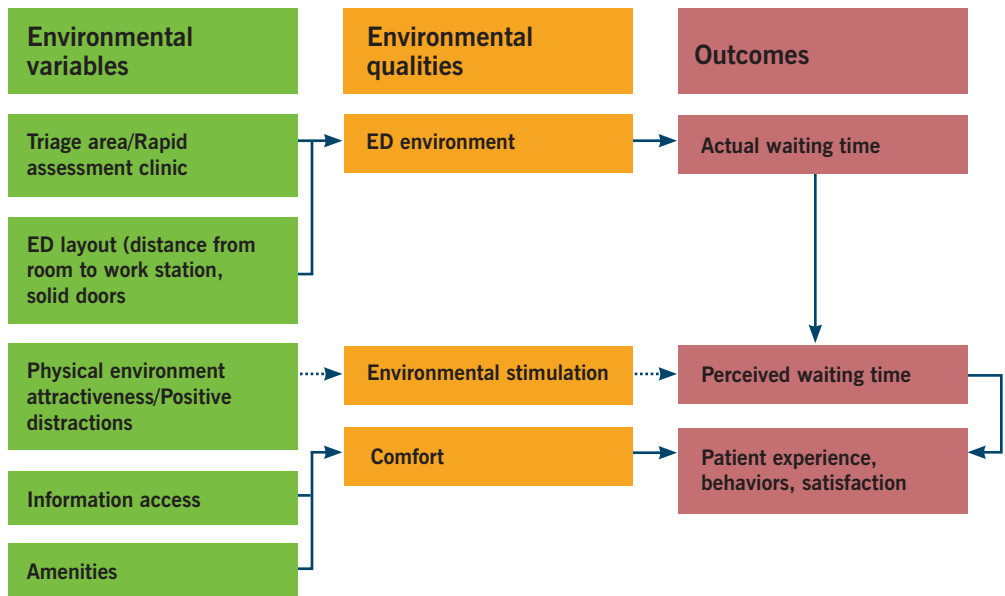
Environmental variables for patient waiting are categorical variables that can be manipulated by experimenters or measured by environment inspection. The exception is physical environment attractiveness which is measured by subjective rating.

A correlation exists between the key outcomes of actual patient waiting time and perceived waiting time, although patients tend to overestimate short waiting times and underestimate long waiting times (Becker & Douglass, 2008).

A patient's cognitive perception plays a significant role in the relationships between patient waiting and patient satisfaction (Pruyn & Smidts, 1998). Actual patient

waiting time was measured by direct observation or using existing medical records. Perceived waiting time was measured by subjective report – patients’ responses to questionnaire surveys. Typically, patient waiting behaviors were directly observed to determine the percentage or number of behaviors in different categories, including continuous behaviors (e.g., reading) and discrete behaviors (e.g., getting out of seat) as well as distraction activities, non-distraction activities, and restless/anxious behaviors.

FIGURE 5
Model of environmental variables examined in relationship to patient waiting



F. Staff Efficiency

Research has identified staff efficiency outcomes that can be influenced by physical environment (Figure 6). These outcomes include staff travel time and distance, team communication, circadian misalignment, nurse response time to patient calls, medication processing time, and surgeon/anesthesiologist performance (e.g., percentage of correct judgments, accuracy of cystic and artery clipping).

A time-motion study based on the space syntax theory indicated that linear integration, a measure of the centrality of the assigned room with regard to the entire nursing unit layout, has a positive impact on the number of nurse entries to patient rooms and the nursing station (Hendrich, Chow, Bafna, Choudhary, Heo, & Skierczynski, 2009).

Several studies found that nurses working in radial units walked less and spent more time with patients than nurses working in rectangular units (e.g., Shepley & Davies,

2003; Trites, Galbraith, Sturdavant, & Leckwart, 1970). Dividing a large, 38-bed unit into four pods, each served by two RNs, significantly reduced nurse walking steps and significantly increased the amount of time nurses spent in direct patient care (Donahue, 2009). One study found that nurses in units with decentralized nursing stations spent more time on all types of communication activities except communication with other nurses for patient information and spent more time on patient care activities in patient rooms (Gurascio-Howard & Malloch, 2007). Another study found that nurses in decentralized units had fewer verbal interactions with other nurses (Dutta, 2008).

Patient room layout is an important factor impacting staff efficiency. An open configuration providing an immediate global view of conditions in the caregiver zone and the location of equipment was perceived as best supporting nursing tasks (Pati, Cason, Harvey, & Evans, 2010). Nurses in a NICU spent less time traveling after moving from an old unit with six rooms (each room contained 1 to 5 beds) to a new unit with an open floor plan (Shepley, 2002).

Multiple studies examined the benefits of wireless communication systems. Having a wireless device equipped with audio and visual display significantly reduced nurse response time to patient calls and increased nurse-initiated and team-initiated communications (Guarascio-Howard, 2011). Compared with indirect page communication, direct cellular communication was associated with better response rate and lower error rate in communication (Ortega, Taksali, Smart, & Baumgaertner, 2009). ICU staff reported in a questionnaire survey that wireless email communication helped: improve speed and reliability of communication, improve coordination of team members, reduce staff frustration, and provide faster, safer patient care (O'Connor, Friedrich, Scales, & Adhikari, 2009).

The impact of other environmental variables on staff efficiency has also been studied. A drug counter and pharmacy fixture specially designed to fit the ergonomic needs of pharmacists helped reduce prescription filling time and reduce pharmacist travel distance (Lin, Barker, Hassall, & Gallelli, 1988). Decentralized satellite pharmacies close to nursing units and on-line computerized physician order-entry systems might reduce technician and nurse work time as well as reduce pharmacy order-processing time (Poley, Bouwmans,

Hanff, Roos, & van Ineveld, 2004; Wietholter, Sitterson, & Allison, 2009). Noise increased errors and path length per movement when surgeons performed laparoscopy tasks (Moorthy, Munz, Dosis, Bann, & Darzi, 2003). Several studies identified the benefits of music for anesthesia monitoring and surgical tasks (e.g., Sanderson, Tosh, Philp, Rudie, Watson, & Russell, 2005). Bright light during the night shift helped reduce circadian misalignment in nightshift workers, helping reduce sleep disorders, fatigue, gastrointestinal disturbances, impaired performance, and declined safety (Crowley, Lee, Tseng, Fogg, & Eastman, 2003).

Environmental variables for staff efficiency are categorical variables that can be manipulated by experimenters or designers. The exception is linear integration, a metric calculated using architectural drawings and space syntax software.

Staff efficiency outcomes were measured using a variety of methods. Staff travel was measured by direct observation (e.g., videotaping, link analysis), work sampling studies (nurses using PDAs to record their locations and activities), pedometers worn by nurses, and indoor position systems that tracked radio-frequency identification (RFID) badges worn by staff.

Methods to measure team communication included observation, audio recording, interview, and questionnaire. Saliva sampling and radioimmunoassay analysis was used to determine circadian misalignment. Nurse response time to patient calls was measured by observation and questionnaire survey. Computer simulation, questionnaire, and data from medical records or architectural drawings were the main methods for measuring medication processing time and surgeon/anesthesiologist performance.

FIGURE 6

Model of environmental variables examined in relationship to staff efficiency



G. Staff Satisfaction

Multiple environmental variables have been found to impact healthcare staff’s job satisfaction (Figure 7). Nurses’ self-reported daily exposure to daylight correlated positively with job satisfaction (Alimoglu & Donmez, 2005). Staff working in single-patient rooms reported higher satisfaction with the physical environment,

higher job satisfaction, and lower work stress than staff working in open bays (Harris, Shepley, & White, 2006; Shepley, Harris, & White, 2008). Nurses working in acuity-adaptable, single maternity care rooms that enabled patients to stay in one room throughout the intra- and post-partum periods and accommodated staff and family were more satisfied than nurses working in traditional maternity units with separate rooms for labor/delivery and postpartum care (Janssen, Harris, Soolsma, Klein, & Seymour, 2001).

Noise is a major source of stress and annoyance and has a negative impact on staff (Morrison, Haas, Shaffner, Garrett, & Fackler, 2003). Applebaum and colleagues (2010) reported that noise was positively correlated with stress, stress negatively related to job satisfaction, and job satisfaction negatively correlated with turnover intent.

Many before-after studies compared staff satisfaction in new versus old healthcare environments. These studies typically focused on bundled environmental modifications. Berry and Parish (2008) reported that nursing staff working in a new unit featuring 100 percent single rooms, larger space, more natural light, more handwashing stations, and more staff break rooms were more satisfied and less stressed. Rice, Ingram, and Mizan (2008) reported that administrative and professional staff's job satisfaction significantly increased after a primary care facility moved from a converted Victorian house that was cramped, noisy, and provided minimal privacy, comfort, and decoration to a spacious, new, purpose-built facility that provided more light, greater comfort, and novel artwork.

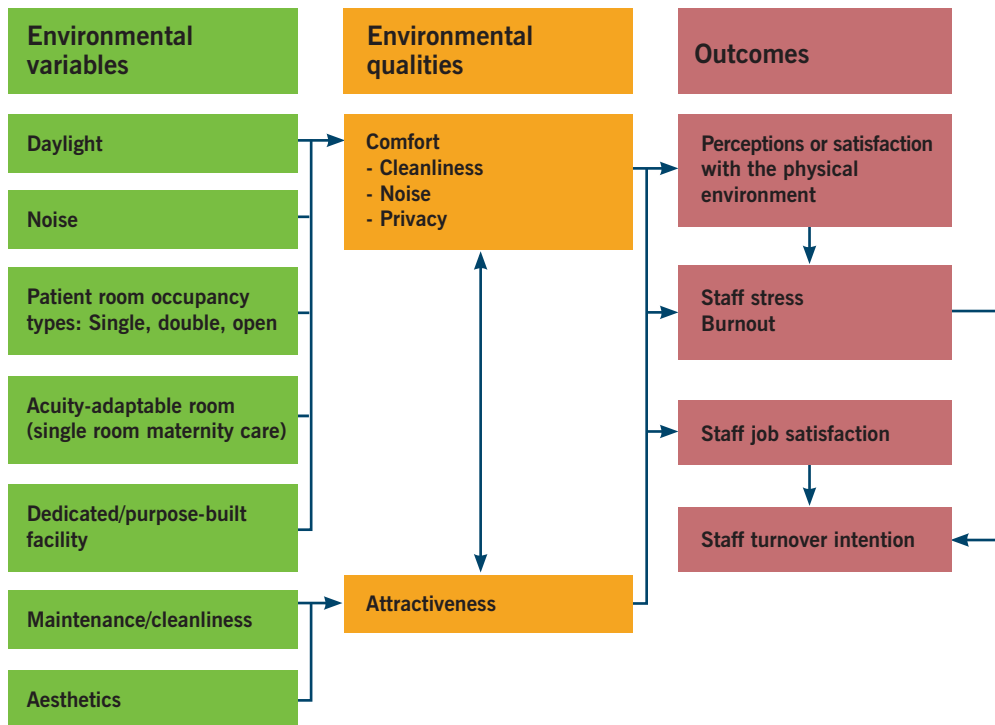
Several studies examined the relationship between staff's perception of physical environment and job satisfaction. Cannon and others (2008) found significant relationships between some staff-perceived environment qualities, such as facility cleanliness and availability of phones, with overall job satisfaction. A survey study by Djukic and colleagues (2010) revealed a group of nurses who negatively perceived their physical work environment, and that the nurses' perception of the work environment positively related to their job satisfaction.

Several environmental factors such as patient room occupancy, acuity-adaptable room, and bundled environmental changes are categorical variables manipulated by designers or researchers. Noise was measured directly by sound level meters or indirectly by staff perception of noise level. Daylight exposure was self-reported by

staff members and categorized as less than 3 hours exposure per day or 3 hours or more exposure per day.

Outcome variables include staff stress, job satisfaction, burnout, intent to turnover, and perception of the physical environment. The vast majority of outcomes were measured using questionnaire scales, some of which are well-developed and validated: Job Satisfaction Scale, Nurses' Intent to Stay Questionnaire, Rehabilitation Job Satisfaction Inventory, PedQL Staff Satisfaction Coworker Module, Maslach Burnout Inventory, and Work Related Starin Inventory. Staff stress was measured using questionnaire scales as well as physiological methods such as electrocardiography (ECG) monitoring and salivary hormone analysis.

FIGURE 7
Model of environmental variables examined in relationship to staff satisfaction





IV. HEALTHCARE ENVIRONMENTAL VARIABLES

All healthcare environmental variables found during the exploration of the seven high-priority topics discussed in this report are listed in alphabetical order in Table 3. Each identified variable is accompanied by a definition and a summary of the metrics and measurement tools used to study the variable’s impact on different healthcare outcomes. A detailed summary of the cited research can be found in the topical summary sections (noted in parentheses following the term name in Table 3) in the Results chapter and in the article analysis table in the *Appendix* at <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>

Table 3 Healthcare environmental variables

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Acoustic ceiling tile (Patient satisfaction)	Ceiling tiles that absorb sound reflected off hard surfaces and can be used in a grid or direct-glued to a solid ceiling deck. Typically porous, these products accept and trap sound/vibration and allow it to dissipate before leaving the products (ASI Pro Audio Acoustics, 2010).	<ul style="list-style-type: none"> - Yes/no, before/after - Noise Reduction Coefficient (NRC) - A measure for rating the overall sound-absorption performance of a material when used in an enclosed architectural space such as an office where sound is being reflected at many angles of incidence. Specifically, it is the 4 frequency averaged absorption coefficients @ 250, 500, 1000 and 2000 Hz, rounded to the nearest 0.05. A material with NRC < 0.50 is a poor absorber, and NRC > .80 is a very good absorber (Armstrong, 2010). 	<p>Design manipulation</p> <ul style="list-style-type: none"> - First, sound-reflecting ceiling tiles (13 mm solid painted plaster board tiles) were installed. Four weeks later, the ceiling tiles were replaced with sound-absorbing ceiling tiles (40 mm Ecophon high density resin bonded glass wool with a painted surface) of nearly identical appearance (Hagerman et al., 2005).

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Acuity-adaptable room, including single-room maternity care (Medical errors, Patient satisfaction, Staff satisfaction)	Rooms designed with sufficient space and provision for equipment, medical gases, and power to accommodate any level of patient acuity (Evans, Pati & Harvey, 2008). Single-room maternity care refers to maternity care rooms where families are admitted and stay throughout the intrapartum and postpartum periods. The rooms are spacious and include amenities for families. They differ from the traditional care model which requires patients to transfer between multiple rooms, depending upon their care status. (Janssen et al., 2001).	- Yes/no, before/after (Hendrich, Fay, & Sorrells, 2004; Janssen et al., 2001)	Design manipulation - The coronary critical care unit and medical step-down unit were redesigned and combined into one acuity-adaptable unit (Hendrich, Fay, & Sorrells, 2004). - Survey responses from a same group of nurses were collected 6 months before and 3 months after moving from a traditional unit to a single-room maternity care unit (Janssen et al., 2001).
Air pressure difference between adjacent spaces (positive/negative pressure room) (HAIs)	Positive pressure room: a room supplied with enough air pressure to prevent air in corridors and adjacent areas from entering the room. Negative pressure room: a room where enough air has been evacuated to prevent air from flowing out of the room and into adjacent areas (Sehulster et al., 2004).	- Yes/no (Gustafson et al., 1982)	Design manipulation/tracer gas studies - Air flow studies were conducted using pure sulfur hexafluoride (SF6) as a tracer gas. The gas was released at a steady rate in the positive-pressure room. The concentration of gas in the corridor and nearby rooms was measured using Wilkes-Miran single-beam infrared portable spectrophotometer connected to a Rikadenki recorder (Gustafson et al., 1982).
Alcohol-based hand rub (HAIs)	A preparation containing alcohol that is designed to be applied to the hands for the purpose of reducing the number of viable microorganisms on the hands. In the United States, these preparations usually contain 60%–95% ethanol or isopropanol (Boyce & Pittet, 2002).	- Alcohol-based hand rub versus water/soap sinks (Cohen et al., 2003) - Manually operated versus automatic dispensers (Larson et al., 2005) - Bed-to-sink/dispenser ratio (Kaplan & McGuckin, 1986)	Design manipulation/site inspection - Comparison of units with different dispensers/sinks (Cohen et al., 2003; Larson et al., 2005)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Amenities (Patient satisfaction, Patient waiting)	Features of health services that do not relate directly to clinical effectiveness but may enhance the client's satisfaction and willingness to return (Brown, Franco, Rafeh, & Hatzell, 1998).	<ul style="list-style-type: none"> - Type of amenities (Cusack et al., 2010) - Level of amenities: high level of amenities (windows, maple furniture, sofa chairs, soundproofing walls, private bathrooms) versus low amenities (old, 'high-tech, low-touch', dark, small bathrooms) (Janssen, Klein, Harris, Soolsma, & Seymour, 2000), amenities such as décor and entertainment facilities appropriate for children (Judkins, 2003) 	<p>Environmental inspection/audit</p> <ul style="list-style-type: none"> - Seven amenities presented in the waiting room (comfy chair, magazine and puzzle book, plasma TV, paintings on walls, views from windows, computer, potted plants) reacted to by patients on questionnaires (Cusack et al., 2010) <p>Design manipulation</p> <ul style="list-style-type: none"> - New single-room maternity care unit with more amenities versus old rooms (Janssen et al., 2000) - New ED dedicated to pediatric patients with décor and entertainment appropriate for children (Judkins, 2003)
Antimicrobial-finished textile product (HAIs)	Textile products containing antimicrobial agents (e.g., silver, quaternary ammonium chloride, chitosan) which show antibacterial activity against a wide range of microorganisms (Takai et al., 2002).	<ul style="list-style-type: none"> - Various textile materials containing different antimicrobial agents, e.g., Ag. Zn. Ammonium Zeolite and chitosan (Takai et al., 2002). 	<p>Research manipulation</p> <ul style="list-style-type: none"> - Testing of five textile materials containing Ag. Zn. Ammonium Zeolite and chitosan, to various extents, and an untreated control material (Takai et al., 2002)
Attractiveness, physical environment (Patient satisfaction, Patient waiting, Staff satisfaction)	Aesthetic appeal of the physical environment, including the surrounding external environment, the architectural design, facility upkeep and cleanliness, and other physical elements (Becker & Douglass, 2008).	<ul style="list-style-type: none"> - Physical environment attractiveness score (summation of ranks) (Becker & Douglass, 2008) - Attractiveness rating on 5-point scale (Pruyn & Smidts, 1998) - Two types of design: an old cement building (transferred from a juvenile hall, ugly and depressing, dimly lighted, glare, stuffy, noisy) versus a new facility (pleasant-looking wood-paneled cottages where staff felt freer, lighter, and more positive; well lighted, adequate ventilation, quiet) (Folkins, O'Reilly, Roberts, & Miller, 1977) - Appealing room versus typical room (Swan et al., 2003) 	<p>Subjective rating</p> <ul style="list-style-type: none"> - Four photos of each of six facilities were presented to six university graduate students in non-design majors. The students were asked to rank the environments from most attractive (6) to least attractive (1). The ratings from all students regarding one facility were summed to create an environmental attractiveness score with a higher score reflecting a more attractive environment (Becker & Douglass, 2008) - Perceived attractiveness, measured on four attributes: atmosphere, cleanliness, spaciousness and climate on a 5-point scale by patients (Pruyn & Smidts, 1998) <p>Design manipulation</p> <ul style="list-style-type: none"> - Appealing, hotel-like rooms featured wood furniture, decorator art, carpeted floors, crown molding, and ceramic tile baths (Swan et al., 2003) - Pleasant-looking wood-paneled cottages where staff felt freer, lighter, and more positive; well lighted, adequate ventilation, quiet (Folkins et al., 1977)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Barcode-assisted dispensing system (Medical errors)	A medication dispensing system that uses barcodes to ensure that the correct medication, in its correct dose and formulation, is being dispensed (Poon et al., 2006).	- Yes/no, before/after (Poon et al., 2006)	Design manipulation - A dedicated repacking center (for affixing a barcode onto each medication if the manufacturer had not already done so) was built to implement a barcode-assisted dispensing system in 3 configurations. In 2 configurations, all doses were scanned once during the dispensing process. In the third configuration, only 1 of several doses of the same medication being dispensed was scanned (Poon et al., 2006).
Bed alarms, medical vigilance system (bed sensors connected to a nurse call system) (Patient falls)	A passive sensor array, including bed exit sensors, embedded into a coverlet around the patient bed's mattress and connected to the nurse call system (Spetz et al., 2007).	- Presence versus absence (Spetz et al., 2007)	Experimental manipulation - The medical vigilance system was installed on 42% of beds in a nursing unit. Outcomes of patients on these beds were compared with outcomes of patients on beds without the system (Spetz et al., 2007)
Bedrail and other physical restraints (Patient falls)	Physical restraints: mechanical or manual devices used to limit a patient's physical mobility (Capezuti et al., 1998). Bedrail: a rail or board running along the side of a patient bed; often used to prevent easy egress from the bed (Hanger et al., 1999).	- Nighttime bed rail use (Capezuti et al., 2002) - Physical restraints use (Capezuti et al., 1998) - Bed rail use (Hanger et al., 1999) - Bed rail use versus no use (Van Leeuwen et al., 2001)	Observation - Nighttime bed rail uses were classified into several levels – bilateral rail use, one-side rail use, no use of side rail (Capezuti et al., 2002) - Levels of physical restraints used in nursing homes were directly observed and classified into several levels: vest, wrist/ankle, belt, pelvic, geriatric/recliner chairs, wheelchairs with fixed tray tables (Capezuti et al., 1998) - In a fall-prevention program, bed rail use was reduced through policy change and education (Hanger et al., 1999) Incidence/accident reports - Bed rail use data were collected from patient incident forms (Van Leeuwen et al., 2001)
Bedside assortment picking (BAP) trolley (Medical errors)	A new type of drug trolley with separate compartments for ward-specific stock and patient-specific medicines. Equipped with a wireless laptop that connects to electronic medication administration records and guides the nurse to the correct location of a drug (Ros & de Vreeze-Wesselink, 2009).	- Yes/no, before/after (Ros & de Vreeze-Wesselink, 2009)	Design manipulation - A new type of drug trolley – bedside assortment picking trolley – was developed and introduced to replace a conventional trolley (Ros & de Vreeze-Wesselink, 2009)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Computerized physician order entry (CPOE) (Medical errors)	Computer-based systems for automating the medication ordering process. A basic CPOE ensures standardized, legible, complete orders by accepting only those orders that are typed and in a standard and complete format (Kaushal & Bates, 2001).	- Yes/no, before/after (King, Paice, Rangrej, Forestell, & Swartz, 2003)	Design manipulation - A commercially available CPOE system developed by Eclipsys was implemented in two inpatient wards. The CPOE system was originally introduced as Carevision, underwent periodic product upgrades, and is now commercially available as Sunrise Clinical Manager (King et al., 2003)
Computerized (automatic) reminder of hand hygiene (HAIs)	A computerized system providing prerecorded, audio/visual messages instructing healthcare personnel to wash their hands before exiting the room or within 10 seconds of exiting the room. The system monitors room entry/exit and handwashing device usage (Swoboda et al., 2004).	- Yes/no (Swoboda et al., 2004)	Research manipulation - The installation of an automatic reminding device (Swoboda et al., 2004)
Copper-silver ionization system (HAIs)	A system that reduces Legionella colonization of a hospital water supply by introducing positively charged copper and silver ions into the water system (Modol et al., 2007).	- Presence/absence (Modol et al., 2007).	Design manipulation The installation of a copper-silver ionization system (Modol et al., 2007).
Daylight (Medical errors, Staff satisfaction)	Light originating from the sun that reaches Earth's surface after reflecting off the sky's vault (Zunde & Bougdah, 2006).	- Hours of exposure to direct daylight in a typical work day (less than 3h versus 3h or more) (Alimoglu & Donmez, 2005) - Average hours of daylight/darkness for each month (Booker & Roseman, 1995)	Questionnaire survey - Self-reported by a question asking about length of exposure in a personal data collection form (Alimoglu & Donmez, 2005). Existing data - Existing data from public weather service (Booker & Roseman, 1995)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Distraction (Medical errors)	An external stimulus causing observable responses from healthcare workers without disrupting the ongoing, productive activity. Distractions (Flynn et al., 1999).	<ul style="list-style-type: none"> - Distraction condition versus non-distraction condition (Pluyter et al., 2010) - Number of distractions per pharmacist per half hour (Flynn et al., 1999) 	<p>Experimental manipulation</p> <ul style="list-style-type: none"> - In one experimental condition, subjects listened to popular songs combined with social conversation irrelevant to the surgical task and non-optimal laparoscope navigation (Pluyter et al., 2010). <p>Video recording of actual work</p> <ul style="list-style-type: none"> - Two video cameras recorded prescription-filling operations from two different angles throughout each eight-hour study day. The videotapes were reviewed simultaneously to record time of interruption or distraction, prescription-filling task affected, type of interruption or distraction, reason for the interruption or distraction, and study participant affected (Flynn et al., 1999)
Emergency Department, layout (Patient waiting)	Spatial configuration of the ED, including treatment rooms, work stations, and other components (Hall et al., 2008).	<ul style="list-style-type: none"> - Distance from treatment room to work station - Solid door versus soft curtain (Hall et al., 2008) 	<p>Environmental inspection/audit</p> <ul style="list-style-type: none"> - Nine experimental conditions defined by three directions of approach to the patient and three conditions of IV pole location (Hall et al., 2008)
Falls - Multifaceted environmental intervention (Patient falls)	Simultaneous modification of multiple aspects of the physical environment for the purpose of reducing patient falls and injuries (Becker et al., 2003; Brandis, 1999).	<ul style="list-style-type: none"> - Before versus after the implementation of a fall-prevention program including environmental modifications (Becker et al., 2003; Brandis, 1999) 	<p>Design manipulation</p> <ul style="list-style-type: none"> - Environmental modification based on environmental hazard check and discussion with staff and administrators (lighting, chair and bed height, floor surfaces, room clutter, grab bars, walking aids) together with staff training, resident education, exercise and hip protectors) (Becker et al., 2003)
Hand hygiene devices, number of (HAIs)	The number of staff-accessible handwashing sinks (Kaplan et al., 1986).	<ul style="list-style-type: none"> - Bed-to-sink/dispenser ratio (Kaplan et al., 1986) 	<p>Design manipulation/site inspection</p> <ul style="list-style-type: none"> - Dividing the total number of beds in one unit by the number of sinks/dispensers in that unit (Kaplan et al., 1986)
Head-mounted display (Staff efficiency)	A scanning retinal display that uses a laser to project a monochromatic red image onto a transparent monocle which then reflects the image on the wearer's retina. The device keeps patients' vital signs within view of the anesthesiologist at all times, precluding the need to look at a patient monitor (Liu et al., 2009).	<p>Monitoring display type</p> <ul style="list-style-type: none"> - Head-mounted display versus standard monitoring equipment (a video graphics array screen mounted within the anesthesia machine) (Liu et al., 2009) 	<p>Experimental manipulation</p> <ul style="list-style-type: none"> - Subjects were asked to perform simulated monitoring tasks when the HMD was used versus not used (Liu et al., 2009).

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
High-efficiency particulate air (HEPA) filter (HAIs)	A high-efficiency air filter that removes at least 99.97% of airborne particles measuring 0.3 micrometers (μm) in diameter (Sehulster et al., 2004). Can be portable or installed in an HVAC system.	- Yes/no (Barnes & Rogers, 1989; Hahn et al., 2002)	<p>Design manipulation</p> <ul style="list-style-type: none"> - Before/after installation of HEPA filter (Barnes & Rogers, 1989) <p>Site inspection</p> <ul style="list-style-type: none"> - One unit wing with HEPA filters (including some rooms with laminar air flow) versus a wing without HEPA filters (Hahn et al., 2002)
HEPA filters, location of (HAIs)	The locations of HEPA filters in an HVAC system (Crimi, et al, 2006).	- Central (inside main air ducts) versus peripheral (at the openings of ducts) (Crimi, et al, 2006)	<p>Site inspection</p> <ul style="list-style-type: none"> - Hospital departments with central HEPA filters and departments with peripheral HEPA filters were identified and compared (Crimi et al., 2006)
Illumination level (illuminance) (Medical errors, Staff efficiency)	The intensity of luminous flux (Stein, 1997).	<ul style="list-style-type: none"> - Lux (1 lux=1 lumen/m²) - Footcandle (1 ftc = 10.764 lux) - Bright light versus normal room lighting (Crowley et al., 2003) 	<p>Photometer</p> <ul style="list-style-type: none"> - Photometer (model IL1350, serial 2048, International Light Inc., Newburyport, MA) with an illuminance sensor (model SCD110, serial 1366, International light). Eight measurements were taken, starting 6 inches from the end of the conveyor belt and every 12 inches thereafter. The amount of illumination represents the mean of the eight measurements taken daily for seven days (Buchanan et al., 1991). <p>Design manipulation</p> <ul style="list-style-type: none"> - Bright light (BL) exposure during night shifts compared with normal room lighting. Bright light (~5000 lux) was produced by 3 light boxes (61.0 cm wide, 77.5 cm high, 12.1 cm deep, cool white fluorescent lamps, Apollo Light Systems Inc., Orem, UT) set on the perimeter of a large, round table facing the center of the table. Normal room light is about 150 lux (Crowley et al., 2003).

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Information access (Patient waiting)	Patient access to information regarding ED process (time to see a doctor/consultant, blood draw) and medical and therapeutic plans (Tran et al., 2002).	<ul style="list-style-type: none"> - Yes versus no (Tran et al., 2002) - Before versus after (Papa et al., 2008) 	<p>Experimental manipulation</p> <ul style="list-style-type: none"> - In the intervention group, ED process information and medical information were provided to each patient every 15 minutes. The control group received regular care (Tran et al., 2002) - An instructional waiting room video explaining what patients should expect during ED visits played continuously on a TV set in the waiting room (Papa et al., 2008)
Interior finish material (HAIs, Patient falls)	Material covering interior surfaces such as ceiling, floors, and walls (Calkins et al., 2011; Noskin et al., 2000).	<ul style="list-style-type: none"> - Flooring type: carpet versus vinyl (Donald et al., 2000; Healey, 1994); with carpet versus without carpet (Simpson et al., 2004); linoleum, VCT, ceramic tile (Calkins et al., 2011); carpet, vinyl, fabric, wood, rubber, etc. (Noskin et al., 2000) - Flooring pattern: pattern size (no, small [less than 1"], medium [1'-6"], large pattern [>6"]) (Calkins et al., 2011) 	<p>Research manipulation</p> <ul style="list-style-type: none"> - Testing of different materials (Noskin et al., 2000) - Installation of a new carpet flooring (Donald et al., 2000) - Incidence/accident reporting - Data about flooring types were gathered from the accident forms completed by nurses (Healey, 1994) <p>Environmental inspection/audit</p> <ul style="list-style-type: none"> - Existing flooring materials were examined through environmental inspection (Simpson et al., 2004)
Interruption (Medical errors)	Cessation of productive activity before completing a prescription-filling task, due to any externally imposed, observable, or audible reason. Interruptions can be caused by staff looking at people passing through the ambulatory care pharmacy and related to prescription-processing questions (Flynn et al., 1999). Situation in which a nurse ceased a medication preparation or administration task in order to attend to an external stimulus (Westbrook et al., 2010).	<ul style="list-style-type: none"> - Number of interruptions per pharmacist per half hour (Flynn et al., 1999) - Number of interruptions during one medication administration (Westbrook et al., 2010) 	<p>Video recording</p> <ul style="list-style-type: none"> - See "distraction" <p>Observation</p> <ul style="list-style-type: none"> - Observers (registered nurses and physicians) used a structured observational tool on a PDA to record number of interruptions that a nurse experienced (Westbrook et al., 2010)
Laminar air flow (LAF) (HAIs)	HEPA-filtered air blown into a room at a rate of 90 ± 10 feet/min in a unidirectional pattern with 100 ACH–400 ACH (Sehulster et al., 2004).	<ul style="list-style-type: none"> - Yes/no (Barnes & Rogers, 1989) 	<p>Design manipulation</p> <ul style="list-style-type: none"> - Before/after the installation of LAF (Barnes & Rogers, 1989)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Light fixture (luminaire) (Medical errors)	A complete lighting unit consisting of a light source (one or more lamps), and the parts designed to position the light source and connect it to the power supply. Parts for protecting the light source or ballast and for distributing the light may be included. (National Fire Protection Association, 2010)	- Different lighting conditions determined by supplemental lighting fixtures and color filters (Buchanan et al., 1991)	Design manipulation - The installation of supplemental light fixtures and the removal of color filters (Buchanan et al., 1991)
Medication distribution system (Staff efficiency)	A system for preparing and distributing medications for the treatment of patients in healthcare settings (Poley et al., 2004).	Medication distribution system type: - A decentralized, patient-orientated, ready-to-use drug distribution system with satellite pharmacies close to the patient units versus a ward stock system in which routinely used drugs are issued by the hospital's central pharmacy, which is located in a neighboring building, and stored in cupboards on the wards (Poley et al., 2004)	Design manipulation - Patient units that used different medication distribution systems were compared (Poley et al., 2004)
Mobile air-treatment unit that uses nonthermal-plasma reactors (HAIs)	A portable device utilizing nonthermal-plasma reactors to destroy microorganisms and electrostatically capture particles and molecular residues for the purpose of reducing airborne bioburden in high-risk areas (Bergeron et al., 2007).	- On versus off; presence/absence (Bergeron et al., 2007)	Research manipulation/Site inspection - In an operating room with volume of 118 m ³ , airborne concentration was measured when the air treatment was turned on versus off; in a hematology unit, airborne fungal level in one room with the unit was compared to the airborne fungal level in the control room (Bergeron et al., 2007)
Music (Staff efficiency)	The art of arranging sounds in time so as to produce a continuous, unified, and evocative composition, as through melody, harmony, rhythm, and timbre (The Free Dictionary).	- Type of music (activating music, deactivating music, no music) (Miskovic, et al, 2008); (rock music, classic, no music) (Sanderson et al., 2005)	Experimental manipulation - Music played on a computer with a constant volume of 35 dB (Miskovic et al., 2008)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Noise (Medical errors, Patient falls, Patient satisfaction, Staff efficiency, Staff satisfaction)	<p>Auditory stimulus, such as a change in loudness, bearing no informational relationship to the presence or completion of the task. Sound: a change in loudness bearing some informational relationship with the task at hand (Flynn, et al, 1996).</p> <p>A sound that is loud, unpleasant, unexpected, or undesired (The Free Dictionary).</p>	<ul style="list-style-type: none"> - Equivalent sound level (Leq) per half hour (Flynn et al., 1996); Equivalent sound pressure level (Laeq) (weighted average sound pressure level in dBA, constant noise level that would result in the same total sound energy being produced over a given period) (Hagerman et al., 2005; Morrison, et al, 2003); minimum and maximum sound level (Morrison et al., 2003) - Reverberation time (time needed for the sound pressure level to decrease by 60 dB) measured in central areas and two patient rooms in the unit (Hagerman et al., 2005) - Auditory events (alarm, telephone, etc.) (Morrison et al., 2003); Number of unpredictable/controllable/uncontrollable sounds per minute (Flynn et al., 1996) - Perception of noise (Applebaum et al., 2010) - Alarms and overhead paging heard frequently, infrequently, never used (Calkins et al., 2011) - Noise versus quiet conditions (Moorthy et al., 2003) 	<p>Acoustic measurement</p> <ul style="list-style-type: none"> - Sound levels were continuously recorded in decibels (A scale) by a noise-logging dosimeter (Quest Electronics Noise-Logging Dosimeter, model M28-12) located at a 70 degree angle above the main prescription-filling area; the Leq was calculated for each half hour using the methods described by Taylor & Lipscomb (1978) for analyzing decibel levels that change over time (Flynn et al., 1996) - Sound pressure levels recorded continuously by a Quest Advanced 1900 precision integrating logging sound level meter (Morrison et al., 2003) - Acoustic measurement by a third-party company (Hagerman et al., 2005) <p>Videotape recording</p> <ul style="list-style-type: none"> - Two video cameras placed in inconspicuous locations recorded ambient sounds. The videotapes were synchronized with the time that each patient's prescription set was being filled in order to determine which sounds affected performance (Flynn et al., 1996). <p>Questionnaire survey</p> <ul style="list-style-type: none"> - Items about perceived noise in M. D. Anderson Patient Contact Survey (Applebaum et al., 2010) <p>Environmental inspection/audit</p> <ul style="list-style-type: none"> - Environmental inspection performed by hospital staff using the Falls Environment Evaluation Tool (FEET) (Calkins et al., 2011) <p>Experimental manipulation</p> <ul style="list-style-type: none"> - Operating theatre background noise at 80 to 85 dB (Moorthy et al., 2003)
Nursing station, layout – decentralized, centralized (Patient falls, Staff efficiency)	<p>Spatial arrangement of nurse work stations in a nursing unit (Dutta, 2008; Gurascio-Howard & Malloch, 2007; Hendrich et al., 2004).</p>	<ul style="list-style-type: none"> - Types: decentralized versus centralized (Dutta, 2008; Gurascio-Howard & Malloch, 2007; Hendrich et al., 2004) 	<p>Design manipulation</p> <ul style="list-style-type: none"> - Environmental changes implemented during a nursing unit renovation (Hendrich et al., 2004) - New unit with 9 decentralized nursing stations versus old unit with 2 centralized nursing stations (Dutta, 2008) - Centralized nurse station design (one centralized station in unit) versus decentralized nurse station design (12 alcoves near patient rooms) (Gurascio-Howard & Malloch, 2007) - Two units in each of three hospitals: one with a centralized nursing station design and the other with a decentralized nursing station design (Zborowsky et al., 2010)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Nursing unit shape/ layout (Staff efficiency)	Spatial arrangement of patient care rooms and nursing stations in nursing units (Donahue, 2009; Shepley, & Davies, 2003; Trites et al., 1970).	<ul style="list-style-type: none"> - Type of unit design: pod design; circular, rectangular; racetrack (Donahue, 2009; Shepley, & Davies, 2003; Trites et al., 1970) - Linear integration (space syntax) (Hendrich et al., 2009). 	<p>Design manipulation</p> <ul style="list-style-type: none"> - Pod design (a nursing unit was divided into four pods, each covered 100 feet, two per hallway. Each served eight rooms and was staffed by two RNs) versus a racetrack design (two, 200-foot parallel hallways, with rooms totaling 20 beds along one hallway and 18 beds along the other; patient rooms on the outer sides, a central nursing station, utility room, and patient kitchen between hallways; three pathways connect the long hallways). (Donahue, 2009) - Dense radial configuration (circular design with patient rooms radiating around the circumference and a nurse station at the center, 10 beds, 8,100 SF, 2 nurses, carpeted, with low-volume radio) versus double-corridor rectangular/racetrack (nurse station/support space in the core, patient rooms on the perimeter wall, 24 beds, 18,500 SF, 5-10 nurses, resilient flooring) (Shepley, & Davies, 2003) - 12 units, three types of layout, four units in each type: radial, single-corridor rectangular, double-corridor rectangular (Trites et al., 1970) <p>Measurement using architectural drawings and computer software</p> <ul style="list-style-type: none"> - Linear integration (a measure of the centrality of a space with respect to the entire layout). The integration of a space such as a patient room is computed by mapping the layout of the space onto a unique network of straight lines representing potential movement paths through it. Each space then maps onto one or more individual lines that pass through it; distances between spaces are described as the number of intermediate lines between them (Hendrich et al., 2009).

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Patient bathroom design (Patient falls)	Architectural and interior design of bathrooms containing bath and toilet facilities for patients (Calkins et al., 2011).	<ul style="list-style-type: none"> - Private versus shared or no bathroom; open versus closed door; 18" space on the opening side of bathroom door versus no space; bathroom located on footwall versus headwall; toilet on side wall versus across from entrance; two bars on both sides of toilet in bathroom, one bar, no bar (Calkins et al., 2011) 	<p>Environmental inspection/audit</p> <ul style="list-style-type: none"> - Environmental inspection performed by hospital staff using the Falls Environment Evaluation Tool (FEET) (Calkins et al., 2011)
Patient room layout (Patient falls, Staff efficiency)	Spatial arrangement of architectural elements and equipment in patient rooms (Calkins et al., 2011; Pati et al., 2010).	<ul style="list-style-type: none"> - Designated family space versus no designated family space (Calkins et al., 2011) - Direction of approach to the patient (right-handed, left-handed, and neutral-handed configurations) - The presence or absence and location of an intravenous (IV) line to the patient, using a mobile pole (IV pole on patient's left, on patient's right, and no-IV pole) (Pati et al., 2010) 	<p>Environmental inspection/audit</p> <ul style="list-style-type: none"> - Environmental inspection performed by hospital staff using the Falls Environment Evaluation Tool (FEET) (Calkins et al., 2011) <p>Experimental manipulation</p> <ul style="list-style-type: none"> - Nine experimental conditions defined by three directions of approach to the patient and three conditions of IV pole location (Pati et al., 2010)
Patient room occupancy (HAIs, Patient satisfaction, Staff efficiency, Staff satisfaction)	The number of patients per patient room—one (single room, private room), two (double room), four (multi-bed open bays) (Ben-Abraham et al., 2002; Nguyen Thi, Briancon, Empereur, & Guillemin, 2002; Shepley, Harris, & White, 2008).	<ul style="list-style-type: none"> - Single versus double or multiple occupancy room (Ben-Abraham et al., 2002); Single family room versus open bay (Shepley, Harris, & White, 2008); Single room versus 2 or 3 patients per room (Nguyen Thi, Briancon, Empereur, & Guillemin, 2002); Double room versus six-bed room (Soufi et al., 2010); New open NICU versus old unit with 1-5 bed patients rooms (Shepley, 2002); Proportion of beds in single rooms (Gardner et al., 1973) 	<p>Design manipulation</p> <ul style="list-style-type: none"> - Conversion of an open bay unit to a single-room unit with separated sinks (Ben-Abraham et al., 2002) - Comparison between three types of patient spaces: single rooms from an all-single-room NICU, single rooms and open bays from another NICU (Shepley, Harris, & White, 2008) <p>Site inspection</p> <ul style="list-style-type: none"> - The study wards were divided into two groups based on the percentage of beds in single rooms <40% versus >85% (Gardner et al., 1973) <p>Existing data from medical or administrative records</p> <ul style="list-style-type: none"> - Health characteristics including admission room (double/common) were collected at admission (Soufi et al., 2010) - Old NICU: six rooms for 1-5 beds each versus new, remodeled NICU: open unit (Shepley, 2002)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Pharmacy equipment (Staff efficiency)	Fixtures and equipment used in the pharmacy area for the purpose of preparing and distributing medications (Lin et al., 1988).	Pharmacy equipment type - Baker drug counter, Systamodule pharmacy fixture, exiting equipment (Lin et al., 1988)	Experimental manipulation - Simulated experiments were conducted in four conditions: baseline—existing layout, Baker drug counter, Systamodule pharmacy fixture, both Baker drug counter and Systamodule pharmacy fixture (Lin et al., 2009)
Physical configuration of drug stock shelves (Staff efficiency)	Spatial arrangement of drug items including the amount of space between drug items on shelves (Flynn et al., 2002).	- Separation and space between items versus tightly packed items on shelves (Flynn et al., 2002)	Environmental inspection - A pharmacy's drug stock was classified into one of two systems: stocked with space between items or tightly packed onto shelves (Flynn et al., 2002)
Physical proximity (HAIs)	A risk factor of nosocomial infection. A patient is considered to be in physical proximity when he/she is a roommate or neighbor of a patient with an infectious disease, or when he/she stays in the room after the patient with the infectious disease has left (Chang & Nelson, 2000).	- Yes/no, whether or not a patient was roommate or neighbor of a patient with diarrhea, or stayed in the room after the patient with diarrhea left (Chang & Nelson, 2000)	Mapping patient rooms - With medical records data, determine whether or not a patient was a roommate or neighbor of a patient with diarrhea, or stayed in the room after the patient with diarrhea left (Chang & Nelson, 2000)
Positive distractions (Patient satisfaction, Patient waiting)	A set of environmental features or conditions that have been found by research to effectively reduce stress. These features or conditions include nature and certain types of music, companion animals, laughter or comedy, and certain types of art (Ulrich, 1991).	- Yes/no, before/after; Art intervention (Nanda, 2010); Visual-auditory stimuli presented on a plasma TV (Pati & Nanda, 2011)	Design and experimental manipulation - Art intervention included plasma TV screens showing looped video of nature scene photos, still nature photographs printed on canvas, window films with garden scenes and cloud patterns (Nanda, 2010) - Five distraction conditions as defined by types of visual and audio stimuli—slide show of nature images, virtual Ambient Art, natural aquarium, and accompanying audio (Pati & Nanda, 2011) - 42x52 photographic quality mural of a mountain stream in a spring meadow, mounted from the ceiling at bedside so patients could view it supine, nature sounds played with a portable tape recorder (Diette et al., 2003) - Classical music and home-made movie (mainly scenic views) provided by an Eyetrek system (Olympus, Japan) (Lee et al., 2004)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Rapid assessment clinic/pod/zone (Patient waiting)	An ED area for quick clinician assessment and procedures on patients whose disposal is readily apparent for whom required interventions can be quickly undertaken, and for problems that do not require prolonged assessment or decision-making. Generally adapted from existing ED space, it is a novel intervention for reducing ED waiting time (Ardagh et al., 2002; Bullard et al., 2011).	- RAC versus no RAC (Ardagh et al., 2002; Bullard et al., 2008)	Experimental manipulation - RAC operated in odd weeks and did not operate in even weeks during the study period (Ardagh et al., 2002) - ED spaces were converted to RAP (Bullard et al., 2008)
Subfloor (Patient falls)	Rough floor serving as a base under a finished floor (Simpson et al., 2004)	- Type: wood versus concrete (Simpson et al., 2004)	Environmental inspection/audit - Existing subfloor materials were examined through environmental inspection (Simpson et al., 2004)
Surface cleaning—cleaning, disinfection, sterilization (HAIs)	<p>Cleaning: removal of visible soil and organic contamination from a device or surface, using either the physical action of scrubbing with a surfactant or detergent and water, or an energy-based process such as ultrasonic cleaners with appropriate chemical agents; thorough cleaning is an important step before high-level disinfection and sterilization (Sehulster et al., 2004).</p> <p>Disinfection: compared to sterilization, a less lethal process of microbial inactivation that eliminates virtually all recognized pathogenic microorganisms but may not eliminate all microbial forms (e.g., bacterial spores) (Sehulster et al., 2004).</p> <p>Sterilization: use of a physical or chemical procedure to destroy all microbial life, including large numbers of highly-resistant bacterial endospores (Sehulster et al., 2004).</p>	- Type of cleaning processes and products (Carling et al., 2006)	Research Manipulation - Before and after the intervention to improve environmental cleaning—a structured, multidisciplinary educational intervention was developed for the environmental services staff of participating hospitals. The role of the staff in infection prevention and safety improvement within the hospital was explained, and expectations with respect to cleaning HTOs were defined (Carling et al., 2006).

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Ultraviolet germicidal irradiation (HAIs)	Use of ultraviolet radiation to kill or inactivate microorganisms (Sehulster et al., 2004).	- On versus off (McDevitt et al., 2008)	Research manipulation - Testing of the effectiveness of upper room UVGI in a simulated real world environment in an experimental chamber (McDevitt et al., 2008)
Ventilation grilles, location of (HAIs)	Arrangement of ventilation grilles on ceilings and walls (Beggs et al., 2008).	- Ceiling versus wall ventilation; High versus low (Beggs et al., 2008)	Research manipulation - Various ventilation regimes set up in computer simulation using Fluent 6.2 CFD software (ANSYS, Canonsburg, PA) with an unstructured tetrahedral grid containing approximately 540,000 cells. A standard k-e turbulence model with enhanced wall treatment was used, and a no-slip condition was applied at the walls (Beggs et al., 2008).
Ventilation, natural (HAIs)	Movement of outdoor air into a space through intentionally provided openings such as windows, doors, or non-powered ventilators) (Sehulster et al., 2004).	- Natural versus mechanical ventilation (Escombe et al., 2007)	Site inspection - 70 naturally ventilated clinical rooms where infectious patients are likely to be encountered were compared with 12 mechanically ventilated, negative-pressure respiratory isolation rooms built post-2000 (Escombe et al., 2007)
Ventilation rate (HAIs)	The rate at which air enters and leaves a building, space, or room (EPA, n.d.).	- Air changes per hour (ACH) - Cubic feet per minute (CFM) - Cubic meter per hour (absolute ventilation rate) (Escombe et al., 2007)	Tracer gas concentration decay technique - With all windows and doors closed, carbon dioxide (CO ₂) was released and mixed well with room air using large fans to create a spatially uniform CO ₂ concentration in the room. CO ₂ concentrations were measured throughout the room at 1-minute intervals using a centrally located infrared gas analyzer. ACH were calculated as the gradient of the straight line through the natural logarithm of CO ₂ concentration plotted against time in hours (Escombe et al., 2007; Menzies et al., 2000)

Table 3 Healthcare environmental variables (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Wireless technology (Staff efficiency)	Technology enabling the transfer of information over a distance without the use of electrical conductors or wires (Guarascio-Howard, 2011; O'Connor et al., 2009).	<p>Communication system type</p> <ul style="list-style-type: none"> - The addition of a wireless device for nurse communication with display and audio versus traditional communication infrastructure using nurse call system, telephones, health unit coordinator (HUC) stations (Guarascio-Howard, 2011) - Wireless e-mail over a GSM cellular network using handheld devices versus baseline (receive-only numeric pagers, overhead paging, physical searches for staff, handwritten messages left in or near patient charts, and e-mail accessed by computers) (O'Connor et al., 2009) 	<p>Design manipulation</p> <ul style="list-style-type: none"> - A wireless device was added to the existing communication system to help nurses receive team communications and alarms (Guarascio-Howard, 2011) - The installation of a wireless e-mail system using a GSM cellular network and handheld devices (O'Connor et al., 2009)
Workroom layout (Staff efficiency)	Spatial arrangement of equipment in a workroom (Lu & Hignett, 2009).	- Spatial layout of soiled workroom (Lu & Hignett, 2009)	<p>Measurement on architectural drawings</p> <ul style="list-style-type: none"> - Examination of the location of equipment in floor plans (Lu & Hignett, 2009)

V. HEALTHCARE OUTCOME MEASURES

All healthcare outcome measures found during the exploration of the seven high-priority topics discussed in this report are listed in alphabetical order in Table 4. Each identified outcome is accompanied by a definition and a summary of the metrics and methods used to measure that outcome. A detailed summary of the cited research can be found in the topical summary sections (noted in parentheses following the term name in Table 4) in the Results chapter and in the article analysis table in the Appendix at: <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>.

Table 4 Healthcare outcome measures

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Adverse drug event (ADE) (Medical errors)	Harm caused by a drug or the use of a drug (Nebeker, Barach, & Samore, 2004). Potential drug event defined as dispensing errors that can harm patients if not intercepted before medication administration (Poon et al., 2006).	- Number of ADEs per 1,000 patient days; percentage of prescriptions involved in potential ADEs divided by the total number of prescriptions (King, Paice, Rangrej, Forestell, & Swartz, 2003; Poon et al., 2006)	Physician review of error reports - Two physicians accessed the medication error database and reviewed all original incident reports. Severity was reclassified based on patient impact as an ADE, potential ADE, or other. (King, Paice, Rangrej, Forestell, & Swartz, 2003) - Each of two board-certified internists independently reviewed and rated the severity of each dispensing error by using an explicit set of criteria. Each physician-reviewer determined whether the patient could have had an injury if the dispensing error had reached the patient, defined errors that could harm patients as potential ADEs, and classified potential ADEs as significant, serious, and life-threatening (Poon et al., 2006)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Anxiety (Patient satisfaction)	<p>State anxiety: reflects a transitory emotional state or condition of the human organism that is characterized by subjective, consciously perceived feelings of tension and apprehension and heightened autonomic nervous system activity.</p> <p>Trait anxiety: denotes relatively stable individual differences in anxiety proneness; refers to a general tendency to respond with anxiety to perceived threats in the environment (Spielberger, Gorsuch, and Lushene, 1970).</p>	<ul style="list-style-type: none"> - The Spielberger State-Trait Anxiety Inventory (S-STAI) score - the summation or average of items (Diette et al., 2003; Rice, Ingram, & Mizan, 2008; Routhieaux & Tansik, 1997) 	<p>Questionnaire survey</p> <ul style="list-style-type: none"> - Six-item short version of the state anxiety measure (calm, tense, upset, relaxed, content, worried) from the Spielberger State-Trait Anxiety Inventory was included in a questionnaire completed by a patient twice – while waiting to begin the procedure and the second day following the procedure (Diette et al., 2003)
Bacterial growth (HAIs)	An increase in the amount of bacteria on surfaces (Lankford et al., 2006).	<ul style="list-style-type: none"> - Confluent growth (CG, bacterial growth so heavy that individual colonies are not recognized for counting), no confluent growth (NCG, 1-388 cfus), no growth (NG) (Lankford et al., 2006) 	<p>Surface culture/biology analysis</p> <ul style="list-style-type: none"> - The cultures for VRE and PSAE were performed using culture impression plates (Remel, Lenexa, KS) containing tryptic soy agar plus 5% sheep blood. For each surface tested, approximately 10 cm² was touched 5 times with culture impression plates to ensure that the inoculated area was sampled. All plates were incubated at 35° C in ambient air and evaluated at 48 hours to determine the presence of VRE or PSAE. Bacterial growth on culture impression plates was quantified and organisms identified to the species level to confirm that the bacteria that were inoculated onto the surfaces were the bacteria recovered. (Lankford et al., 2006)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Bioaerosol concentration (HAIs)	The amount of airborne particles that are biological in origin (Bergeron et al., 2003).	- cfu (colony-forming unit)/m ³ (Bergeron et al., 2003)	<p>Air sampling using biocollector and biology analysis</p> <ul style="list-style-type: none"> - Concentrations of airborne biological particles were determined with biocollectors (MAS 100; Merck) from a height of 1 meter above the floor and operating at 100 L/min for 5 minutes. Petri dishes containing Sabouraud culture media were used for fungal analysis, and standard plate count agar dishes were used to evaluate the total mesophilic flora. Fungal cultures were incubated at 27° C and the number of colony-forming units was determined on days 3, 5, and 7 (Bergeron et al., 2003). <p>Computational fluid dynamics [CFD] study</p> <ul style="list-style-type: none"> - Fluent 6.2 CFD software (ANSYS, Canonsburg, PA) with an unstructured tetrahedral grid containing approximately 540,000 cells was used to estimate bioaerosol concentration in various simulated conditions (Beggs et al., 2008)
Burnout (Staff satisfaction)	A prolonged psychological response to chronic emotional and interpersonal stressors on the job and defined by three dimensions –emotional exhaustion (EE), depersonalization (D), and low personal accomplishment (PA). EE refers to feelings of being overextended and depleted of emotional and physical resources. D refers to a negative, callous, or excessively detached response to various aspects of the job. PA refers to feelings of incompetence and a lack of achievement and productivity at work (Alimoglu & Donmez, 2005).	- Self-reported burnout scores (Alimoglu & Donmez, 2005)	<p>Questionnaire survey</p> <ul style="list-style-type: none"> - Maslach Burnout Inventory (22 items in 3 subscales 'emotional exhaustion', 'depersonalization', 'personal accomplishment', 5-point scale 0 never to 4 always, [Maslach & Jackson, 1996], Turkey translation [Ergin, 1992]) (Alimoglu & Donmez, 2005; Tyson et al., 2002)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Circadian misalignment (Staff efficiency)	A mismatch between an individual's desired bedtime and the timing of his/her circadian system. Often observed among shift workers and individuals suffering from jet-lag. Usually occurs when individuals attempt to initiate sleep at sub-optimal times during their circadian cycles and, consequently, experience sleep disturbances (Jean-Louis et al., 2008).	<ul style="list-style-type: none"> - DLMO (dim light melatonin onset) based on melatonin level obtained through saliva sampling and radioimmunoassay analysis - Temperature minimum (Tmin) - Amount of re-entrainment (Crowley et al., 2003) 	<p>Saliva sampling and radioimmunoassay analysis</p> <ul style="list-style-type: none"> - Saliva sampling and radioimmunoassay analysis to determine DLMO, Tmin (DLMO + 7 hr), and amount of re-entrainment (not re-entrained [Tmin before the daytime dark/sleep period], partially re-entrained [Tmin during the first half of dark/sleep], or completely re-entrained [Tmin during the second half of dark/sleep]) (Crowley et al., 2003)
Cleaning, thoroughness of terminal cleaning (HAIs)	The amount of high-risk objects cleaned after terminal cleanings (cleanings after discharge) (Carling et al., 2006).	<ul style="list-style-type: none"> - Percentage of objects cleaned after terminal cleanings (Carling et al., 2006) 	<p>Fluorescent marker</p> <ul style="list-style-type: none"> - Objects marked with targeting solutions which fluoresce under black light (Carling et al., 2006)
Endotoxin concentration (HAIs)	The amount of toxins associated with certain bacteria (Menzies et al., 2003).	<ul style="list-style-type: none"> - eu/m³, eu/coupon (Menzies et al., 2003) 	<p>Air sampling</p> <ul style="list-style-type: none"> - Airborne samples for endotoxin measurements were captured on an isopore polycarbonate membrane (Millipore, Bicester, MA, UK) backed by a glass fiber pad (Millipore) with a volumetric air pump (Menzies et al., 2003)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Falls, patient (Patient falls)	<p>There is no universally accepted definition of patient falls. The following definitions are used in literature and practice:</p> <ul style="list-style-type: none"> - An unplanned descent to the floor (or extension of the floor, e.g., trash can or other equipment) with or without injury to the patient, and occurring on an eligible reporting nursing unit. All types of falls are included, whether they result from physiological reasons (fainting) or environmental reasons (slippery floor). - Includes assisted falls which occur when a staff member attempts to minimize the impact of a patient's fall (NDNQi, 2005). - Unintentionally coming to rest on the ground, floor, or other lower level regardless of the cause (Becker et al., 2007). - A sudden, unanticipated change (downward) in body position with or without physical injury (Brandis, 1999). - An accidental collapse to the ground leading to the completion of an accident report form by nursing staff (Donald, Pitt, Armstrong, & Shuttleworth, 2000). - A sudden, unexpected descent from a standing, sitting, or horizontal position, including slipping from a chair to the floor, a patient found on the floor, and an assisted fall (Hitcho et al., 2004). 	<p>Prevalence:</p> <ul style="list-style-type: none"> - Number of patients injured per 1,000 admissions (Brandis, 1999) - Number of injuries per 1,000 patient days (Capezuti et al., 1998) <p>Severity</p> <ul style="list-style-type: none"> - Percentage of falls resulting in injuries of different severity levels (Capezuti et al., 1998; Hanger et al., 1999; Schwendimann et al., 2006; Van Leeuwen et al., 2001) - Number of hip fractures per 100 falls (Simpson et al., 2004) 	<p>Incidence/accident reporting system as described above</p> <ul style="list-style-type: none"> - Nursing home incidence report (Capezuti, 2002) - Routine data collection using incident forms (Hanger et al., 1999) - Falls register of nursing home (Simpson et al., 2004) <p>Radiograph review</p> <ul style="list-style-type: none"> - Radiograph review of hip fractures (Simpson et al., 2004)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Hand hygiene compliance (HAIs)	Adherence with recommendations/guidelines of hand hygiene in healthcare settings (Larson et al., 2005).	<ul style="list-style-type: none"> - Percentage of actual hand hygiene divided by hand hygiene opportunities (Swoboda et al., 2004); - Number of hand touches with new gloves/cleaned hands, used gloves, and no gloves/uncleaned hands per neonate per shift (Cohen et al., 2003); - Number of incidences of hand hygiene per patient per hour; number of incidences of hand hygiene before patient contact per hour (Larson et al., 2005). 	<p>Observation</p> <ul style="list-style-type: none"> - Hand hygiene behavior of staff members whose activities could be directly observed was recorded. At regular intervals, an observer assumed a position that allowed direct observation of the maximum number of contacts between staff members and patients. On the basis of the 8 indications for hand hygiene listed in the recommendations of the CDC hand hygiene guideline, the observer noted when a hand hygiene episode was indicated and whether the staff member used soap or the alcohol sanitizer (Larson et al., 2005) <p>Automatic electronic system</p> <ul style="list-style-type: none"> - The system consisted of electronic beam breakers or motion detectors placed at the threshold of each room to monitor entry and exit of personnel, both staff and visitors. The toilets, sinks, soap, and waterless antiseptic dispensers were fitted with sensors and switches. When a sensor was activated either by the toilet being flushed, soap or foam being dispensed, or water flowing through the tap, a radio signal was sent to the computer indicating that the switch was opened or closed (Swoboda et al., 2004).

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Job satisfaction (Staff satisfaction)	A pleasurable or positive emotional state in an individual, resulting from the appraisal of that person's job or job experiences (Berry & Parish, 2008).	- Self-reported job satisfaction scores (Alimoglu & Donmez, 2005; Applebaum et al., 2010; Berry & Parish, 2008; Djukic et al., 2010; Folkins et al., 1977; Harris et al., 2006; Jason et al., 2002; Shepley et al., 2008; Tyson et al., 2002; Varni et al., 2004)	Questionnaire survey <ul style="list-style-type: none"> - Job Satisfaction Scale (JSS), a 5-item subscale from the Nurse Stress Index by Harris, Hingley, and Cooper (1988) (Harris et al., 2006; Shepley et al., 2008) - Work Satisfaction Questionnaire (14 items, 5-point scale from 1 never satisfies me to 5 highly satisfies me, [Hackman & Oldham, 1980] (Alimoglu & Donmez, 2005) - One item in a staff questionnaire (Berry & Parish, 2008) - Nurses' Intent to Stay Questionnaire (NISQ), Job satisfaction 7 items, turnover intent 4 items (Applebaum et al., 2010) - A five-item Likert type job satisfaction scale with response category varying among items and rescaled to a 7-point scale (Djukic et al., 2010) - Minnesota Satisfaction Questionnaire (Weiss, Dawis, England, & Lofquist, 1967) - GM Faces Scale (Kunin, 1955), a simple, well-validated measure including seven drawings of faces with facial expressions ranging from a frown to a smile (Folkins et al., 1977) - Rehabilitation Job Satisfaction Inventory (Wright & Terrian, 1987) including 15 items, agreement with the statement on a 5-point scale, the final score of job satisfaction was calculated from 4 items (satisfied with job, plan on staying, the best compared to past jobs, look forward to going to work) (Jason et al., 2002) - Job Satisfaction (Warr et al., 1979), satisfaction with extrinsic and intrinsic features of the job as well as overall job satisfaction, 16 items (Tyson et al., 2002) - PedQL Staff Satisfaction Coworker Module (Varni et al., 2004)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Length of stay (HAIs)	Period of time during which a patient is confined to a hospital or other health facility (NLM MeSH).	- Days (Ben-Abraham et al., 2002)	Medical charts - Review of medical records (Ben-Abraham et al., 2002)
Medication administration procedural failure (Medical errors)	Failure to comply with specific medication administration procedures, including failure to read a medication label, failure to check patient's identification, temporary storage of medication in an unsecured environment, failure to record on a medication chart, use of a nonaseptic technique, failure to check pulse/blood pressure/blood glucose level (when applicable), failure of 2 nurses to check preparation of a dangerous drug or IV medication (Moorthy et al., 2003).	- Percentage of medications with procedural failures (Westbrook et al., 2010).	Direct observation - Observers (registered nurses and physicians) used a structured observational tool on a PDA to record nursing procedures related to medication administration (Westbrook et al., 2010)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Medication error (Medical errors)	Error that occurs while ordering, transcribing, dispensing, administering, or monitoring medications, irrespective of the outcome (Kaushal & Bates, 2001).	<ul style="list-style-type: none"> - Number of dispensing errors per pharmacist per hour Flynn et al., 1999) - Percentage of prescriptions involved in errors divided by the total number of prescriptions (Buchanan et al., 1991; Flynn et al., 1999; Westbrook et al., 2010) - Percentage of prescriptions with near-errors corrected and corrected staff (Flynn et al., 2002) - Number of nurse medication errors per month (Booker & Roseman, 1995) - Severity of error: five severity rating levels (1 - little or no effect on patient, 2 - likely to lead to increase in level of care, 3 - likely to lead to permanent reduction in bodily functioning, 4 - likely to lead to a major permanent loss of function, 5 - likely to lead to death); two categories (major errors - levels 4-5, minor errors - levels 1-3) (Westbrook et al., 2010) 	<p>Direct observation & expert evaluation</p> <ul style="list-style-type: none"> - Filled prescriptions evaluated by researcher to detect deviations from physician's orders (Flynn et al., 1999; Flynn et al., 2002) - After the routine final check by a pharmacist but before the drug was dispensed to the patient, every prescription was reviewed for content by the observer (Buchanan et al., 1991) - A trained research pharmacist-observer inspected the medications that had already undergone the usual 3-step dispensing process to look for dispensing errors and classify the error types (Poon et al., 2006) - The direct observation method consists of an observer witnessing the administration of medicines to patients by the nurse. The observer checks the administration of each dose by the nurse with the help of an exact copy of the medication administration record. The observer does not interfere if an error is observed. If the observer estimated that the patient's safety is compromised, a warning is given to the nurse before the medicine is actually taken by the patient (Ros & de Vreeze-Wesselink, 2009). - Observers (registered nurses and physicians) used a structured observational tool on a PDA to record details of medication administered and compare the data with patients' medication charts to determine whether the medication administered differed from what was ordered (Westbrook et al., 2010). <p>Adverse event reporting system</p> <ul style="list-style-type: none"> - A passive reporting system. The nurse and physician involved in a medication error complete an incident report and document the incident. The severity of patient harm is rated as none, mild, moderate, or severe. Medication errors are then sent to the pharmacy department and entered into a spreadsheet database (King, Paice, Rangrej, Forestell, & Swartz, 2003). - The annual medication error index was measured by the hospital's standard system for reporting adverse events (Hendrich, Fay, & Sorrells, 2004). - Errors were documented on a standard error reporting form completed by the nurse committing the error and/or staff discovering the error (Booker & Roseman, 1995).

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Medication processing time (Staff efficiency)	Amount of time from when a prescriber orders medication, to the pharmacy receiving the order, to the pharmacist completing the order (Wietholter et al., 2009).	<ul style="list-style-type: none"> - Prescription filling time (Lin et al., 1988; Wietholter et al., 2009) - Pharmacist travel distance for filling prescriptions (Lin et al., 1988) 	<p>Computer simulation</p> <ul style="list-style-type: none"> - Prescription filling time measured by computer simulation using a predetermined motion time system (PMT systems), standards determined through consultation with supervising pharmacist and videotaping of pharmacist work (Lin et al., 1988) <p>Medical records</p> <ul style="list-style-type: none"> - Review of medication records (Wietholter et al., 2009) <p>Measurement on architectural drawings</p> <ul style="list-style-type: none"> - Pharmacist travel distance for filling prescriptions was measured and calculated using architectural drawings (Lin et al., 1988)
Mortality (HAIs)	The rate of death from any cause in hospitalized populations (NLM MeSH).	<ul style="list-style-type: none"> - Percentage of deaths/total number of patients (McManus et al., 1992) 	<p>Actual: Medical charts;</p> <p>Expected: Estimated using an equation based on patient characteristics e.g., burn size, age (McManus et al., 1992)</p>
Nosocomial infection (HAIs)	An infection that is acquired in a hospital as a result of medical care; also called hospital-acquired infection (Sehulster et al., 2004).	<ul style="list-style-type: none"> - Number of NIs per 100 admits/ discharges (Modol et al., 2007); - Number of NIs per 1,000 patient days (Swoboda et al., 2004); - Number of hospital-acquired infections per patient (Ben-Abraham et al., 2002); - Risk of infection - Percentage of susceptible patients infected (Escombe et al., 2007) 	<p>Medical charts</p> <ul style="list-style-type: none"> - Infection data were prospectively collected and stored in a computerized database. All infections and antibiotic uses were reviewed by the facility's Infection Control Committee based on pre-existing criteria (McManus et al., 1992) - Physician evaluation according to CDC criteria based on test results of respiratory, serum, or urinary samples (Modol et al., 2007) <p>Model estimation</p> <ul style="list-style-type: none"> - Estimated by Wells-Riley model of airborne infection (Escombe et al., 2007)
Nurse response to patient calls (Staff efficiency)	Amount of time from when a nurse call button is pressed to when the nurse responds to the call (Guarascio-Howard, 2011)	<ul style="list-style-type: none"> - Response time to patient calls (minute) (Guarascio-Howard, 2011) - Patient ratings of nurse response to patient calls (Donahue, 2009) 	<p>Observation</p> <ul style="list-style-type: none"> - Shadowing of nursing activity (Guarascio-Howard, 2011) <p>Questionnaire survey</p> <ul style="list-style-type: none"> - Press Ganey score on nurses' promptness in response to patient calls (Donahue, 2009)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Particulate level (HAIs)	Amount of particles in the air (Bergeron et al., 2003).	- Number of particles/m ³ (Bergeron et al., 2003).	Air Sampling using particle counter - Airborne particle counts were measured over a 1-minute interval with a 6-channel, light-scattering particle counter (CI-500; Climet), operating at a flow rate of 1.7 cubic meters per hour and placed 1.2 meters above floor level (Bergeron et al., 2003)
Patient colonization (HAIs)	Isolation of a targeted pathogen (organism) from the patient (e.g., sputum, wound surface, urine, stool) (McManus et al., 1992).	- Percentage of patients colonized; - Postburn time delay in colonization (McManus et al., 1992)	Microbiology surveillance - Microbiology surveillance was performed for the first 30 days of hospitalization or longer if patients remained in the unit. The surveillance included weekly cultures of sputum, wound surface, urine, and stool. Colonization was defined as isolation of the organism from any site on the body (McManus et al., 1992)
Patient loyalty (Patient satisfaction)	Patient's long-term commitment to a preferred healthcare service provider; a manifestation of attitudes and actual purchasing behaviors (Hsu, Hsu, & Chiu, 2009)	- Willingness to recommend or return, ratings of Likert scale (Nguyen Thi et al., 2002; Swan et al., 2003)	Questionnaire survey - Two questions in Patient Judgments of Hospital Quality questionnaire (PJHQ) about intention of recommending the hospital or returning (Nguyen Thi et al., 2002)
Perception of physical environment (Staff satisfaction)	Quality of the physical environment as perceived by healthcare staff members. May include perceptions of environmental aspects such as quality of the patient care area (comfort and privacy afforded to patients and families due to the design of patient areas), safety (degree of hazard for staff and patients related to facility design), pleasantness (ambiance of the facility design due to specific design features) (Berry & Parish, 2008).	- Subjective rating of physical environment (Berry & Parish, 2008; Harris et al., 2006; Shepley et al., 2008)	Questionnaire survey - Perception of physical environment (quality of patient areas [4 items], safety [3 items], pleasantness [3 items], quality of workspace [6 items]) (Berry & Parish, 2008) - Level of agreement with statement regarding the physical environment, 12 questions, 5-point scale, average score (e.g., quiet, private space for family to be alone, atmosphere tense and stressful for staff/family) (Harris et al., 2006; Shepley et al., 2008)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Satisfaction, patient (Patient satisfaction, Patient waiting)	Degree to which an individual regards a provider's health care service, product, or the manner in which the service or product is delivered as useful, effective, or beneficial (NLM MeSH).	<p>Patient Waiting</p> <ul style="list-style-type: none"> - Overall satisfaction with service (Papa et al., 2008; Pruyn & Smidts, 1998) <p>Patient Satisfaction</p> <ul style="list-style-type: none"> - Scores of Likert type scales or subscales calculated (summation or average of items in the each scale/subscale) (e.g., Groff et al., 2008; Janssen et al., 2000) - Percentage of "excellent" responses (Becker & Douglass, 2008) - Percentage of patients who are dissatisfied (Hendrich, Fay & Sorrells, 2004) - Score of a single question of patient satisfaction (Leather et al., 2003; Lee et al., 2004) 	<p>Questionnaire</p> <ul style="list-style-type: none"> - One question in the survey asked for the overall satisfaction level, 5-point Likert scale, excellent - poor (Papa et al., 2008) - Overall patient satisfaction rated on a 10-point scale (Pruyn & Smidts, 1998) <p>Questionnaire survey (see Appendix for a table of questions and subscales in questionnaires found in literature)</p> <ul style="list-style-type: none"> - Questionnaires (8 subscales - e.g., information and support, being with family and friends, privacy needs, physical environment) were distributed on the day of delivery and completed after delivery and before discharge (Janssen et al., 2000). A questionnaire including 16 items from a patient judgment system (PJS) developed by the Hospital Corporation of America was distributed to patients before and after the movement to a new unit. Patients completed the questionnaires independently or with help from nurses. The completed questionnaires were collected by nurses (Kline et al., 2007). - Patients were offered a questionnaire survey when completing their clinic visits and asked to fill out a questionnaire on-site or mail in the completed questionnaire from home. The quality of care index was the average percentage of "excellent" responses to 4 questions related to care, services, and interactions with staff and doctors (Becker & Douglass, 2008) - Patient Expectation Project standardized tool (Arbor Associates, Inc., Potoskey, MI) measuring how closely patients' experiences meet their expectations (Hendrich, Fay & Sorrells, 2004) - Satisfaction score on a 10 cm visual analog scale (0 =not satisfied, 10 = very satisfied) (Lee et al., 2004)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Staff travel (Time allocation, travel distance) (Staff efficiency)	Physical movements (location, time, duration, frequency, activity type) of healthcare staff members (Shepley, 2002; Zborowsky, 2010).	<ul style="list-style-type: none"> - Nursing activity (20 types), location (31), time data, and nurse type were recorded sequentially (Shepley, 2002) - Frequency and duration of activities (Zborowsky, 2010) - Nurse walking distance (steps per minute, the ratio of travel distance to unit floor area) (Shepley, 2002) 	<p>Observation</p> <ul style="list-style-type: none"> - Observers made rounds of the facility at specific time points and recorded activities. Staff activities were classified in 9 categories (e.g., direct patient care, indirect patient care, nonproductive time), locations in 5 categories (e.g., nurse station, patient room), and 2 other categories (with patient, total not travel) (Trites et al., 1970) - Behavior mapping (recording staff behaviors, locations, time data) (Shepley, 2002) - Videotaping using ceiling-mounted cameras received and processed by custom-made software installed on computers (Pati, Cason, Harvey, & Evans, 2010) - Frequency and duration of activities recorded by a digital timer and visual data charts (Zborowsky, 2010) <p>Work sampling study with PDAs</p> <ul style="list-style-type: none"> - The PDAs were set to vibrate randomly approximately 22 times over a 12-hour period. The nurse then selected her or his location and the most accurate description of the activity being performed (Donahue, 2009) - A personal digital assistant (PDA) vibrated at random times throughout the work shift, prompting nurses to select their location and activity at that moment from a predetermined list of options (Hendrich et al., 2009) <p>Pedometer</p> <ul style="list-style-type: none"> - Electronic pedometer attached to the back of staff's belts (Shepley & Davies, 2003; Donahue, 2009) <p>Indoor positioning system</p> <ul style="list-style-type: none"> - A positioning system tracked radio-frequency identification (RFID) badges worn by participating nurses (Hendrich, 2009) <p>Link analysis</p> <ul style="list-style-type: none"> - Link analysis was used to record and analyze movements among components, e.g., nursing staff, equipment/devices, and furniture. Tasks that occupied the most space, areas that had the highest level of activity (to determine the layout and adjacency requirements of equipment and furniture), and areas needing easiest access were identified (Lu, 2009)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Stress, staff (Staff satisfaction)	A state of mental or bodily tension caused by the imbalance between an individual's environmental demands or perceived demands and the individual's ability or perceived ability to cope with the environmental demands (Stokols & Montero, 2002).	<p>Physiology measures</p> <ul style="list-style-type: none"> - Heart rate (average HR [bpm], minimum, maximum HR for every half-hour period, percent of time in tachycardia [HR>100], number of episodes of ectopy [disturbance of the cardiac rhythm]) (Morrison et al., 2003) - Salivary amylase concentration (units per mL) (Morrison et al., 2003) <p>Psychology measures</p> <ul style="list-style-type: none"> - Self-reported stress and annoyance (Alimoglu & Donmez, 2005; Morrison et al., 2003) 	<p>Electrocardiography (ECG) monitoring</p> <ul style="list-style-type: none"> - A portable cassette battery-driven Holter monitor (GE Marquette 8500 series, Milwaukee, WI) (Morrison et al., 2003) - Salivary hormone analysis - A citric acid impregnated cellulose sponge, salivary amylase field test kits (Morrison et al., 2003). <p>Questionnaire survey</p> <ul style="list-style-type: none"> - Expanded Nurse Stress Scale (ENSS) by French, Lenton, Walters, and Eyles (2000), 59 items in 9 subscales (Harris et al., 2006; Shepley et al., 2008). - Specific Rating of Events Scale, nurses rated how stressed or annoyed "right now" on a scale of 0 for "not at all stressful" or "not at all annoyed" to 100 for "most stress possible" or "most annoyance possible" (Morrison et al., 2003) - Work Related Starin Inventory, 18 items about work-related expectations, stress, interpersonal relations, productivity, working habits, interactions between work and family [Revicki et al., 1991], 4 point scale from 1 surely agree to 4 surely disagree (Alimoglu & Donmez, 2005) - 3 items in a questionnaire developed specifically for the study (Berry & Parish, 2008)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Surface contamination (HAIs)	Presence of pathogens on inanimate surfaces (Anderson et al., 1982).	<ul style="list-style-type: none"> - Number of microorganisms (cfu) per square inch (Anderson et al., 1982); - Bacterial community composition (Harris et al., 2010) 	<p>Swab sampling/biology analysis</p> <ul style="list-style-type: none"> - Surface swab samples were collected from each flooring type using a surface swab kit (SKC, Eighty Four, PA, USA). DNA from the swab washes was extracted with an Ultraclean Microbial DNA Kit (Mo-Bio, Carlsbad, CA, USA) (Harris et al., 2010). Generic analysis - denaturing gradient gel electrophoresis (DGGE) - The DGGE technique is based on the separation of PCR fragments of the same length in a linearly increasing gradient of chemical denaturants. The different fragments melt and, consequently, stop at particular positions in the gel, a transition from helical to partially melted molecule that depends on the base composition of their sequences. The resulting banding pattern represents a profile of the community, and the relative intensity of each band represents the relative abundance of a particular member of the community. Consequently, microbial communities can be quickly analyzed and compared, permitting temporal and spatial analysis within and between communities (Harris et al., 2010)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Surgeon/ anesthesiologist performance (Staff efficiency)	Performance of surgical tasks and anesthesia monitoring tasks (Liu et al., 2009; Miskovic et al., 2008; Sanderson, 2005).	<p>Anesthesiologist performance</p> <ul style="list-style-type: none"> - Number of anesthesia events detected, event detection time(s), frequency of changes in gaze location (changes/minutes), percentage of time looking toward a location - Percentage of correct judgments (abnormality judgments: normal, high, low; trend judgments: steady, increasing, decreasing, fluctuating) (Sanderson, 2005) - Anesthesiologist perception of work efficiency (Liu et al., 2009) <p>Surgeon performance</p> <ul style="list-style-type: none"> - Global task score (the anatomy scores [accuracy of cystic duct and artery clipping] minus the error score [e.g., clipping errors, cutting errors, bleeding], with a minimum score of 0), total task time, instrument travel distances, and surgeons' heart rate (Miskovic et al., 2008) 	<p>Simulation</p> <ul style="list-style-type: none"> - Test scenarios performed on a METI ECS™ (Sarasota, FL) mannequin. Video data were analyzed to determine the onset time of an event (when event symptoms are first visible in the video) and the time of detection (when the participant makes a comment about the event or begins a corrective action). Gaze location was coded using three categories: Anesthesia machine, Patient, and Other (Liu et al., 2009) - LS500 (Xitact) virtual patient laparoscopy simulator, run by a Pentium PC with a high-resolution thin film transistor (TFT) monitor connected to 2 robotic force feedback devices acting as interfaces for the laparoscopic instruments (Miskovic et al., 2008). - The surgical task was to move cylindrical pieces of sponge from one disc to another. Surgical performance was measured by the Imperial College Surgical Assessment Device. When motion tracking sensors attached to the dorsum of both hands move in an electromagnetic field generated by the system, the positional data from the trackers gets converted into data on the number of movements and the path length traversed by each hand using specially developed software (Moorthy et al., 2003). - During simulated monitoring of visual and auditory displays of patients' vital signs (9 anesthesia test scenarios), participants were asked every 50–70 seconds whether one of five vital signs was abnormal and the trend of its direction. Anesthesia simulator (Advanced Simulation Corporation's Body™ physiological and pharmacological engine, connected to an interface largely similar to the Body™ Anesthesia Simulator interface) (Sanderson, 2005). <p>Questionnaire</p> <ul style="list-style-type: none"> - Self-reported work efficiency (Liu et al., 2009)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Surgical errors (Medical errors)	Errors in the performance of surgical procedures. In a laparoscopic task, skill-based errors involved dropped objects and objects placed inaccurately in the disc—either on their side or incompletely within the zone; knowledge-based errors occurred when objects were placed in the wrong zone (Moorthy et al., 2003).	<ul style="list-style-type: none"> - Number of errors in a surgical task (task error score) (Moorthy et al., 2003; Pluyter et al., 2010) 	Surgery simulation system <ul style="list-style-type: none"> - Xitact LC 3.0 virtual reality simulator (Xitact SA, Morges, Switzerland). The clip and cut assessed (CCA) task in the Clip and Cut (C&C) module was used. Task errors were recorded by the simulator (Pluyter et al., 2010)
Team communication (Staff efficiency)	Frequency, formalization, structure, and openness of information exchange between team members (Carmeli, Gelbard, & Goldrieck, 2010)	<ul style="list-style-type: none"> - Number of verbal interactions per hour, length of conversations, number of persons involved in one interaction (Dutta, 2008) - Number of nurse-initiated communications (Guarascio-Howard, 2011) - Communication type, number, time (Guarascio-Howard & Malloch, 2007) - Staff perception of communication (Guarascio-Howard & Malloch, 2007; O'Connor et al., 2009) - Communication between nurse and surgeon (response rate, correct patient ID time, error rate, response time, solution time, communication time, intraoperative case interruptions) (Ortega et al., 2009) 	Observation <ul style="list-style-type: none"> - Staff verbal interactions were manually recorded according to predetermined categories for physical location, participant roles, gender and duration of interactions (Dutta, 2008) - Shadowing of nurses (Guarascio-Howard & Malloch, 2007) - Direct observation with stop-watch (Ortega et al., 2009) Audio recording <ul style="list-style-type: none"> - Analysis of audio recording of team communication (Guarascio-Howard & Malloch, 2007) Interview <ul style="list-style-type: none"> - Interviews regarding staff perceptions of communication, technology, and team-work (Guarascio-Howard & Malloch, 2007) Questionnaire <ul style="list-style-type: none"> - Questionnaire, 49 items, developed by interview, focus group, pretesting. Items included: improved speed of communication, improved reliability of communication, less effort required to communicate, improved physician response times to critical issues, etc. 7 point scale (O'Connor et al., 2009).
Transport, patient intra-hospital transport (Medical errors)	Transport of patients within the hospital (Ulrich & Zhu, 2007)	<ul style="list-style-type: none"> - Number of patient transports between nursing units /month (Hendrich, Fay, & Sorrells, 2004). 	Medical and operational data <ul style="list-style-type: none"> - Data collected from Transition System, Inc. (TSI) by Vanderbilt University Medical Center, Nashville, TN (Hendrich, Fay, & Sorrells, 2004).
Tuberculin conversion and reactivity (HAIs)	TB conversion: indurations of 10 mm or greater with an increase of at least 6 mm more than 1 year after a negative result (<10 mm). TB reactivity: indurations of 10 mm or greater (Menziez et al., 2000).	<ul style="list-style-type: none"> - Ratio (percentage) of healthcare workers with Tuberculin conversion (Menziez et al., 2000); - Ratio (percentage) of patients/visitors with Tuberculin reactivity (Hutton et al., 1990) 	TB skin test <ul style="list-style-type: none"> - Tuberculin conversion is indicated by induration of 10 mm or greater with an increase of at least 6 mm more than 1 year after a negative result (<10 mm) (Menziez et al., 2000)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Turnover intent (Staff satisfaction)	Employees' inclination to voluntarily leave their organization (Haybatollahi, 2009).	- Self-reported turnover intent (Applebaum et al., 2010; Lin et al., 2008)	Questionnaire survey - Nurses' Intent to Stay Questionnaire (NISQ) (turnover intent 4 items) (Applebaum et al., 2010) - Variables measured on 0-100 scale (Lin et al., 2008)
Waiting behavior, patient (Patient waiting)	Behaviors that patients exhibit in waiting rooms (Nanda, 2010; Pati & Nanda, 2011).	- Percentage of behaviors in the following categories: attention (positive distraction, other artwork, toy, book, wall, ceiling, floor, door, window, furniture, people, themselves), physical behavior (calm, fidgety, fine movement, intense), activity (playing with toys, playing with non-toys, non-play activity/ other play), location (out of seat, in seat, parent's lap), social behavior (positive interaction, negative interaction, solitary behavior) (Pati & Nanda, 2011) - Number of discrete behaviors (getting out of seat, entering waiting room, people pacing, changing seat, aggressive behavior) in three, 5-minute periods every 20 minutes (Nanda, 2010)	Observation - Behavioral observations during 20-minute windows over 12 days, snapshot at beginning of each minute, modification of an existing children's observation instrument (Handen, McAuliffe, Janosky, Feldman, & Breaux, 1998) (Pati & Nanda, 2011) - Systematic observation, behavior mapping (Nanda, 2010)

Table 4 Healthcare outcome measures (continued)

TERM (TOPIC SOURCE)	DEFINITION	METRICS	MEASUREMENT METHOD
Waiting time, patient (Patient waiting)	Period of time from when a patient arrives at a clinic or ED to the time his or her consultation/treatment begins (Dexter, 1999).	<p>Actual waiting time</p> <ul style="list-style-type: none"> - ED: patient waiting time to be seen by a doctor (minute) (Ardagh et al., 2002), overall ED length of stay (minute) (Ardagh et al., 2002; Bullard et al., 2008), time from triage to bed (Bullard et al., 2008), ED time from bed to physician (Bullard et al., 2008), time from treatment room to physician (Hall et al., 2008) - Medical office: time spent in waiting room and exam room (Becker & Douglass, 2008) <p>Perceived waiting time</p> <ul style="list-style-type: none"> - Percentage of respondents in categories from 0-5 minutes to more than 30 minutes (Becker & Douglass, 2008) - Subjective rating from "very short" to "very long" (Papa et al., 2008) 	<p>Medical records</p> <ul style="list-style-type: none"> - Data extracted from the ED module of Patient Management System (Ardagh et al., 2002) - Actual waiting time and LOS were extracted from computerized medical records (Tran et al., 2002) - Times were recorded by physicians and retrospectively collected from existing database (Hall et al., 2008) <p>Observation</p> <ul style="list-style-type: none"> - Observer was located in waiting area and hallway outside exam rooms. Time from patient entering the practice until called into exam room by staff, and time from patient entering exam room until leaving the exam room (Becker & Douglass, 2008) <p>Questionnaire</p> <ul style="list-style-type: none"> - Patient perception of how long they waited in the waiting area and in the exam room was assessed on the survey (Becker & Douglass, 2008) - In one question, questionnaire asked patients to rate the wait time on a 4-point scale from very short to very long (Papa et al., 2008)



VI. USING THE GLOSSARY

The glossary in this report was developed using evidence-based methodologies for two important reasons – to provide definitions of environmental terms and outcome measures for seven high-priority healthcare outcome topics and to create a standard reference that can be used by researchers, designers and the entire healthcare team.

A comprehensive set of reference tools have been created for the seven healthcare outcome topics:

- Models depicting the environmental terms and outcome measures found for each topic during a literature review (see models *in Chapter III. Results*)
- Definitions for each environmental term and outcome measure found, along with the metrics and measurement methods used to evaluate the terms and measures (see tables in *Chapter IV. Healthcare Environmental Variables* and *Chapter V. Healthcare Outcome Measures*)
- Matrix summarizing the evidence of the relationships between environmental features and outcome measures. (See <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>).
- Article analysis table with summary information about each study used to develop the glossary – sample and study setting, study design, variables examined, metrics used, and results. (See <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>). For the patient satisfaction topic, a summary of the types of questions asked in various patient satisfaction surveys is also provided.

The glossary can be used for:

- Defining environmental terms and outcome measures for research projects
- Developing environmental research studies

- Exploring the high-priority healthcare topics to identify which environmental features have been studied for their impact on healthcare outcomes
- Identifying metrics and measures that have been used to evaluate the impact of specific environmental features
- Beginning a literature review for an evidence-based design research project
- Identifying key environmental features to include in healthcare projects across the facility life-cycle
- Defining outcome measures to monitor as a component of post-occupancy evaluation and healthcare facility performance improvement projects



VII. CONCLUSION

Over the past decade, our understanding of the associations between the physical healthcare environment and the outcomes associated with the patient, patient's family, staff, and the care organization has made healthy progress. Once considered a passive backdrop to the process of care delivery, the physical design of the care setting is now regarded as an active contributor to the health and well-being of the environment's users and a business driver of healthcare organizations.

Challenges remain, however, in reaching an optimal understanding of the complex and interacting factors that characterize the care environment. Factors from multiple domains – e.g., treatment, workflow, processes, cultures, policies, physical environments, and sociological and psychological processes at the individual and group levels – interact in complex ways in care delivery and healing. Improving patient and staff outcomes and reducing care delivery costs requires a greater, more accurate comprehension of these complex interactions as opposed to the traditional focus of healthcare research in individual, narrowly defined domains. The need for better comprehension of these complex processes is even more crucial at a time when the central focus of healthcare is moving away from treating illnesses and toward promoting health.

A lack of common definitions, tools, measures, and metrics poses a fundamental problem in any research endeavor, let alone the physical environment. As our understanding of the physical environment improved over the past decade, it became increasingly clear that further research and meaningful study outcomes are contingent on having common definitions, tools, and metrics associated with the physical care environment. This glossary project was initiated to address this critical challenge.

An absence of a glossary impacts more than the ability to conduct meaningful, individual research. The lack of a glossary:

- Poses problems in systematic integrative reviews of multiple studies, both quantitative and qualitative

- Creates problems when translating findings to design decisions and when developing design guidelines
- Precludes the development of advanced and more complex theoretical frameworks to capture the interactions between the myriad factors that impact healthcare outcomes; without such frameworks, multi-disciplinary studies might not optimize our understanding of critical phenomena

This glossary project was envisaged in multiple phases. The first phase forms the content of this report and was designed to provide a snapshot of the current state of environmental terms and outcome measures for seven high priority topics. It was not meant to be a comprehensive review of scientific literature. Rather, articles were selected to create a comprehensive list of factors/variables that have been targeted in healthcare environment studies. The objective was to capture in a single document the environmental variables used in healthcare studies, their definitions (conceptual and operational, if provided by the authors), tools and measures used in the studies, and the sources and validation studies associated with such tools and measures, where available.

As underscored in this report, the physical environment has more frequently been measured at the categorical (or nominal) level. Categorical levels of measurement per se do not connote any reduction in the robustness of the studies. Moreover, numerous aspects of the physical environment are amenable only to categorical levels of measurement. The key problem is that higher levels of measurement need to be developed to provide greater analytical power to data analyses. A prerequisite to developing higher levels of measurement is the availability of precise conceptual and operational definitions for the targeted variables.

This is where the glossary project provides a crucial foundation. Future phases of this study will expand the list of terms and definitions in both the healthcare environmental variables and outcome measures. Expanding the glossary will enable researchers to develop more powerful tools and measures and to articulate frameworks that capture the true complexities of the relationship between the built environment and healthcare outcomes.



VIII. NEXT STEPS

Recommended next steps are organized around two major goals: distributing the glossary report and further glossary development.

Distributing the glossary report (November 2011)

Distributing the glossary findings is an important step in the glossary development. This report will be:

- Made available on CHD's website
- Highlighted in a message to CHD community members
- Shared at key conferences and meetings
- Highlighted in a message to communities that work with healthcare environmental and outcome variables
- Used to develop relationships with other key stakeholder groups, with a goal of persuading them to support and adopt these terms
- Shared with post-occupancy evaluation development teams

Further glossary development (November 2011 – October 2012)

A four-pronged approach is envisioned for the second phase of glossary development:

- *Engage interested, multidisciplinary volunteers to assist in the glossary's development*
- *Facilitate additional topic area development in partnership with academic institutions*
- *Examine additional sources of environmental terms and healthcare outcome measures*
- *Develop the Ripple database (an open source, searchable database containing usable and relevant information to help user learn about evidence-based design) to house the glossary and support its development*



IX. APPENDIX

The following tables of article analysis, glossary tables, and matrices of relationships as well as a complete reference list can be found at <http://www.healthdesign.org/chd/research/healthcare-environmental-terms-and-outcome-measures-evidence-based-design-glossary>:

- Healthcare-associated infections
- Medical errors
- Patient falls
- Patient satisfaction
- Patient waiting
- Staff efficiency
- Staff satisfaction

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Healthcare-Associated Infections: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environmental variable	Air pressure difference between adjacent spaces (positive/negative pressure room)	Positive pressure room: a room supplied with enough air pressure to prevent air in corridors and adjacent areas from entering the room. Negative pressure room: a room where enough air has been evacuated to prevent air from flowing out of the room and into adjacent areas (Sehulster et al., 2004).	Yes/no (Gustafson et al., 1982)	Design manipulation/tracer gas studies - Air flow studies were conducted using pure sulfur hexafluoride (SF6) as a tracer gas. The gas was released at a steady rate in the positive-pressure room. The concentration of gas in the corridor and nearby rooms was measured using Wilkes-Miran single-beam infrared portable spectrophotometer connected to a Rikadenki recorder (Gustafson et al., 1982).
	Alcohol-based hand rub	A preparation containing alcohol that is designed to be applied to the hands for the purpose of reducing the number of viable microorganisms on the hands. In the United States, these preparations usually contain 60%--95% ethanol or isopropanol (Boyce & Pittet, 2002).	- Alcohol-based hand rub vs. water/soap sinks (Cohen et al., 2003) - Manually operated versus automatic dispensers (Larson et al., 2005) - Bed-to-sink/dispenser ratio	Design manipulation/site inspection - Comparison of units with different dispensers/sinks (Cohen et al., 2003; Larson et al., 2005)
	Antimicrobial-finished textile product	Textile products containing antimicrobial agents (e.g., silver, quaternary ammonium chloride, chitosan) which show antibacterial activity against a wide range of microorganisms (Takai et al., 2002).	- Various textile materials containing different antimicrobial agents, e.g., Ag. Zn. Ammonium Zeolite and chitosan (Takai et al., 2002)	Research manipulation - Testing of five textile materials containing Ag. Zn. Ammonium Zeolite and chitosan, to various extents, and an untreated control material (Takai et al., 2002)
	Computerized (automatic) reminder of hand hygiene	A computerized system providing prerecorded, audio/visual messages instructing healthcare personnel to wash their hands before exiting the room or within 10 seconds of exiting the room. The system monitors room entry/exit and handwashing device usage (Swoboda et al., 2004).	Yes/no (Swoboda et al., 2004).	Research manipulation - The installation of an automatic reminding device (Swoboda et al., 2004)
	Copper-silver ionization system	A system that reduces Legionella colonization of a hospital water supply by introducing positively charged copper and silver ions into the water system (Modol et al., 2007).	Presence/absence	Design manipulation The installation of a copper-silver ionization system (Modol et al., 2007).
	Hand hygiene devices, number of	The number of staff-accessible handwashing sinks (Kaplan et al., 1986).	Bed-to-sink/dispenser ratio (Kaplan et al., 1986)	Design manipulation/site inspection - Dividing the total number of beds in one unit by the number of sinks/dispensers in that unit (Kaplan et al., 1986)
	HEPA filters, location of	The locations of HEPA filters in anHVAC system (Crimi et al., 2006).	Central (inside main air ducts) versus peripheral (at the openings of ducts) (Crimi et al., 2006)	Site inspection - Hospital departments with central HEPA filters and departments with peripheral HEPA filters were identified and compared (Crimi et al., 2006)

Term	Definition	Metrics	Measurement method
High-efficiency particulate air (HEPA) filter	A high-efficiency air filter that removes at least 99.97% of airborne particles measuring 0.3 micrometers (µm) in diameter (Sehulster et al., 2004). Can be portable or installed in an HVAC system.	Yes/no (Barnes & Rogers, 1989; Hahn et al., 2002)	Design manipulation - Before/after installation of HEPA filter (Barnes & Rogers, 1989) Site inspection - One unit wing with HEPA filters (including some rooms with laminar air flow) vs. another wing without HEPA filters (Hahn et al., 2002).
Interior finish material	Material covering interior surfaces such as ceiling, floors, and walls (Noskin et al., 2000)	Carpet, vinyl, fabric, wood, rubber etc. (Noskin et al., 2000)	Research manipulation - Testing of different materials (Noskin et al., 2000)
Laminar air flow (LAF)	HEPA-filtered air blown into a room at a rate of 90 ± 10 feet/min in a unidirectional pattern with 100 ACH–400 ACH (Sehulster et al., 2004).	Yes/no (Barnes & Rogers, 1989)	Design manipulation - Before/after the installation of LAF (Barnes & Rogers, 1989)
Mobile air-treatment unit that uses nonthermal-plasma reactors	A portable device utilizing nonthermal-plasma reactors to destroy microorganisms and electrostatically capture particles and molecular residues for the purpose of reducing airborne bioburden in high-risk areas (Bergeron et al., 2007).	On versus off; presence/absence (Bergeron et al., 2007)	Research manipulation/Site inspection - In an operating room with volume of 118 m3, airborne concentration was measured when the air treatment was turned on versus off; in a hematology unit, airborne fungal level in one room with the unit was compared to the airborne fungal level in the control room (Bergeron et al., 2007)
Patient room occupancy	The number of patients per patient room—one (single room, private room), two (double room), four (multi-bed open bays) (Ben-Abraham, et al., 2002).	Single versus double or multiple occupancy room (Ben-Abraham, et al., 2002) Proportion of beds in single rooms (Gardner et al., 1973)	Design manipulation - Conversion of an open bay unit to a single-room unit with separated sinks (Ben-Abraham, et al., 2002) Site inspection - The study wards were divided into two groups based on the percentage of beds in single rooms <40% versus >85% (Gardner et al., 1973)
Physical proximity	A risk factor of nosocomial infection. A patient is considered to be in physical proximity when he/she is a roommate or neighbor of a patient with an infectious disease, or when he/she stays in the room after the patient with the infectious disease has left (Chang & Nelson, 2000).	Yes/no, whether or not a patient was roommate or neighbor of a patient with diarrhea, or stayed in the room after the patient with diarrhea left (Chang & Nelson, 2000)	Mapping patient rooms - With medical records data, determine whether or not a patient was a roommate or neighbor of a patient with diarrhea, or stayed in the room after the patient with diarrhea left (Chang & Nelson, 2000)

	Term	Definition	Metrics	Measurement method
	Surface cleaning--cleaning, disinfection, sterilization	<p>Cleaning: removal of visible soil and organic contamination from a device or surface, using either the physical action of scrubbing with a surfactant or detergent and water, or an energy-based process such as ultrasonic cleaners with appropriate chemical agents; thorough cleaning is an important step before high-level disinfection and sterilization (Sehulster et al., 2004).</p> <p>Disinfection: compared to sterilization, a less lethal process of microbial inactivation that eliminates virtually all recognized pathogenic microorganisms but may not eliminate all microbial forms (e.g., bacterial spores) (Sehulster et al., 2004).</p> <p>Sterilization: use of a physical or chemical procedure to destroy all microbial life, including large numbers of highly-resistant bacterial endospores (Sehulster et al., 2004).</p>	Type of cleaning processes and products (Carling, et al, 2006)	<p>Research Manipulation</p> <p>- Before and after the intervention to improve environmental cleaning—a structured, multidisciplinary educational intervention was developed for the environmental services staff of participating hospitals. The role of the staff in infection prevention and safety improvement within the hospital was explained, and expectations with respect to cleaning HTOs were defined (Carling et al., 2006).</p>
	Ultraviolet germicidal irradiation	Use of ultraviolet radiation to kill or inactivate microorganisms (Sehulster et al., 2004).	On versus off (McDevitt et al., 2008)	<p>Research manipulation</p> <p>- Testing of the effectiveness of upper room UVGI in a simulated real world environment in an experimental chamber (McDevitt et al., 2008)</p>
	Ventilation grilles, location of	Arrangement of ventilation grilles on ceilings and walls (Beggs et al., 2008).	Ceiling versus wall ventilation; High versus low (Beggs et al., 2008)	<p>Research manipulation</p> <p>- Various ventilation regimes set up in computer simulation using Fluent 6.2 CFD software (ANSYS, Canonsburg, PA) with an unstructured tetrahedral grid containing approximately 540,000 cells. A standard k-e turbulence model with enhanced wall treatment was used, and a no-slip condition was applied at the walls (Beggs et al., 2008).</p>
	Ventilation rate	The rate at which air enters and leaves a building or a space/room (EPA, n.d.).	<ul style="list-style-type: none"> - Air changes per hour (ACH) - Cubic feet per minute (CFM) - Cubic meter per hour (absolute ventilation rate) (Escombe et al., 2007) 	<p>Tracer gas concentration decay technique</p> <p>- With all windows and doors closed, carbon dioxide (CO₂) was released and mixed well with room air using large fans to create a spatially uniform CO₂ concentration in the room. CO₂ concentrations were measured throughout the room at 1-minute intervals using a centrally located infrared gas analyzer. ACH were calculated as the gradient of the straight line through the natural logarithm of CO₂ concentration plotted against time in hours (Escombe et al., 2007; Menzies, et al., 2000)</p>

	Term	Definition	Metrics	Measurement method
	Ventilation, natural	Movement of outdoor air into a space through intentionally provided openings such as windows, doors, or non-powered ventilators) (Sehulster et al., 2004).	Natural versus mechanical ventilation (Escombe et al., 2007)	Site inspection - 70 naturally ventilated clinical rooms where infectious patients are likely to be encountered were compared with 12 mechanically ventilated, negative-pressure respiratory isolation rooms built post-2000 (Escombe et al., 2007)
Outcome	Bacterial growth	An increase in the amount of bacteria on surfaces (Lankford et al., 2006).	Confluent growth (CG, bacterial growth so heavy that individual colonies are not recognized for counting), no confluent growth (NCG, 1-388 cfus), no growth (NG) (Lankford et al., 2006).	Surface culture/biology analysis - The cultures for VRE and PSAE were performed using culture impression plates (Remel, Lenexa, KS) containing tryptic soy agar plus 5% sheep blood. For each surface tested, approximately 10 cm ² was touched 5 times with culture impression plates to ensure that the inoculated area was sampled. All plates were incubated at 35° C in ambient air and evaluated at 48 hours to determine the presence of VRE or PSAE. Bacterial growth on culture impression plates was quantified and organisms identified to the species level to confirm that the bacteria that were inoculated onto the surfaces were the bacteria recovered (Lankford et al., 2006).
	Bioaerosol concentration	The amount of airborne particles that are biological in origin (Bergeron et al., 2003).	cfu (colony-forming unit)/m ³ (Bergeron et al., 2003).	Air sampling using biocollector and biology analysis - Concentrations of airborne biological particles were determined with biocollectors (MAS 100; Merck) from a height of 1 meter above the floor and operating at 100 L/min for 5 minutes. Petri dishes containing Sabouraud culture media were used for fungal analysis, and standard plate count agar dishes were used to evaluate the total mesophilic flora. Fungal cultures were incubated at 27° C and the number of colony-forming units was determined on days 3, 5, and 7 (Bergeron et al., 2003). Computational fluid dynamics [CFD] study - Fluent 6.2 CFD software (ANSYS, Canonsburg, PA) with an unstructured tetrahedral grid containing approximately 540,000 cells was used to estimate bioaerosol concentration in various simulated conditions (Beggs et al., 2008)
	Cleaning, thoroughness of terminal cleaning	The amount of high-risk objects that are cleaned after terminal cleanings (cleanings after discharge) (Carling et al., 2006)	- Percentage of objects cleaned after terminal cleanings (Carling et al., 2006)	Fluorescent marker - Objects marked with targeting solutions which fluoresces under black light (Carling et al., 2006)

Term	Definition	Metrics	Measurement method
Endotoxin concentration	The amount of toxins associated with certain bacteria (Menziez et al., 2003).	eu/m ³ , eu/coupon (Menziez, et al, 2003)	Air sampling - Airborne samples for endotoxin measurements were captured on an isopore polycarbonate membrane (Millipore, Bicester, MA, UK) backed by a glass fiber pad (Millipore) with a volumetric air pump (Menziez et al., 2003);
Hand hygiene compliance	Adherence with recommendations/guidelines of hand hygiene in healthcare settings (Larson et al., 2005).	- Percentage of actual hand hygiene divided by hand hygiene opportunities (Swoboda et al., 2004); - Number of hand touches with new gloves/cleaned hands, used gloves, and no gloves/uncleaned hands per neonate per shift (Cohen et al., 2003) - Number of incidences of hand hygiene per patient per hour; - Number of incidences of hand hygiene before patient contact per hour.	Observation - Hand hygiene behavior of staff members whose activities could be directly observed was recorded. At regular intervals, an observer assumed a position that allowed direct observation of the maximum number of contacts between staff members and patients. On the basis of the 8 indications for hand hygiene listed in the recommendations of the CDC hand hygiene guideline, the observer noted when a hand hygiene episode was indicated and whether the staff member used soap or the alcohol sanitizer (Larson et al., 2005). Automatic electronic system - The system consisted of electronic beam breakers or motion detectors placed at the threshold of each room to monitor entry and exit of personnel, both staff and visitors. The toilets, sinks, soap, and waterless antiseptic dispensers were fitted with sensors and switches. When a sensor was activated either by the toilet being flushed, soap or foam being dispensed, or water flowing through the tap, a radio signal was sent to the computer indicating that the switch was opened or closed (Swoboda et al., 2004).
Length of stay	Period of time during which a patient is confined to a hospital or other health facility (NLM MeSH).	Days (Ben-Abraham et al., 2002)	Medical charts - Review of medical records (Ben-Abraham et al., 2002)
Mortality	The rate of death from any cause in hospitalized populations (NLM MeSH).	Percentage of deaths/total number of patients (McManus et al., 1992)	Actual: Medical charts; Expected: Estimated using an equation based on patient characteristics e.g. burn size, age (McManus et al., 1992)

	Term	Definition	Metrics	Measurement method
	Nosocomial infection	An infection that is acquired in a hospital as a result of medical care; also called hospital-acquired infection (Sehulster et al., 2004).	<ul style="list-style-type: none"> - Number of NIs per 100 admits/discharges (Modol et al., 2007); - Number of NIs per 1,000 patient days (Swoboda et al., 2004); - Number of hospital-acquired infections per patient (Ben-Abraham et al., 2002); - Risk of infection - Percentage of susceptible patients infected (Escombe et al., 2007) 	<p>Medical charts</p> <ul style="list-style-type: none"> - Infection data were prospectively collected and stored in a computerized database. All infections and antibiotic uses were reviewed by the facility's Infection Control Committee based on pre-existing criteria (McManus et al., 1992) - Physician evaluation according to CDC criteria based on test results of respiratory, serum, or urinary samples (Modol et al., 2007) <p>Model estimation</p> <ul style="list-style-type: none"> - Estimated by Wells-Riley model of airborne infection (Escombe et al., 2007)
	Particulate level	Amount of particles in the air (Bergeron et al., 2003).	Number of particles/m ³ (Bergeron et al., 2003).	<p>Air Sampling using particle counter</p> <ul style="list-style-type: none"> - Airborne particle counts were measured over a 1-minute interval with a 6-channel, light-scattering particle counter (CI-500; Climet), operating at a flow rate of 1.7 cubic meters per hour and placed 1.2 meters above floor level (Bergeron et al., 2003).
	Patient colonization	Isolation of a targeted pathogen (organism) from the patient (e.g., sputum, wound surface, urine, stool) (McManus et al., 1992).	Percentage of patients colonized; Postburn time delay in colonization (McManus et al., 1992)	<p>Microbiology surveillance</p> <ul style="list-style-type: none"> - Microbiology surveillance was performed for the first 30 days of hospitalization or longer if patients remained in the unit. The surveillance included weekly cultures of sputum, wound surface, urine, and stool. Colonization was defined as isolation of the organism from any site on the body (McManus et al., 1992)

	Term	Definition	Metrics	Measurement method
	Surface contamination	Presence of pathogens on inanimate surfaces (Anderson et al., 1982).	Number of microorganisms (cfu) per square inch (Anderson et al., 1982); Bacterial community composition (Harris et al., 2010)	<p>Swab sampling/biology analysis</p> <p>- Surface swab samples were collected from each flooring type using a surface swab kit (SKC, Eighty Four, PA, USA). DNA from the swab washes was extracted with an Ultraclean Microbial DNA Kit (Mo-Bio, Carlsbad, CA, USA) (Harris et al., 2010).</p> <p>Generic analysis - denaturing gradient gel electrophoresis (DGGE)</p> <p>- The DGGE technique is based on the separation of PCR fragments of the same length in a linearly increasing gradient of chemical denaturants. The different fragments melt and, consequently, stop at particular positions in the gel, a transition from helical to partially melted molecule that depends on the base composition of their sequences. The resulting banding pattern represents a profile of the community, and the relative intensity of each band represents the relative abundance of a particular member of the community. Consequently, microbial communities can be quickly analyzed and compared, permitting temporal and spatial analysis within and between communities (Harris et al., 2010)</p>
	Tuberculin conversion & reactivity	TB conversion: indurations of 10 mm or greater with an increase of at least 6 mm more than 1 year after a negative result (<10 mm). TB reactivity: indurations of 10 mm or greater (Menzies et al., 2000).	- Ratio (percentage) of healthcare workers with Tuberculin conversion (Menzies et al., 2000); - Ratio (percentage) of patients/visitors w/ Tuberculin reactivity (Hutton et al., 1990).	<p>TB skin test</p> <p>- Tuberculin conversion is indicated by induration of 10 mm or greater with an increase of at least 6 mm more than 1 year after a negative result (<10 mm) (Menzies et al., 2000)</p>

Healthcare-Associated Infections: Article analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Anderson, R. L., Mackel, D. C., Stoler, B. S., & Mallison, G. F. (1982). Carpeting in hospitals: An epidemiological evaluation. <i>Journal of Clinical Microbiology</i> , 15 (3), 408-415.	Flooring material	Carpet vs. vinyl tile flooring	Microorganism contamination on floor surface; Patient colonization; Nosocomial infection rate	# of microorganisms per square inch; Type of microorganisms found in patients and flooring; # of patients with community-acquired and hospital-acquired infections	Experiment	The level of microorganism contamination was higher on carpeted floor than on bare vinyl-tile floor. The same types of organisms initially recovered from the carpet in patient rooms were found on patients. No difference in infection rate was found between carpeted and non-carpeted rooms.	Two patient rooms (one had new carpet installed) in a pediatric hospital	18 carpet samples and 6 vinyl floor samples in each sampling period (total 58 periods); 23 patients in carpeted rooms and 36 in non-carpeted rooms.
Barnes, R. A., & Rogers, T. R. (1989). Control of an outbreak of nosocomial aspergillosis by laminar airflow isolation. <i>Journal of Hospital Infection</i> , 14 (2), 89-94.	Construction work; High-efficiency particulate air (HEPA) filters; Laminar air flow (LAF)	Bone marrow transplant (BMT) unit near the construction site vs. a control unit and outdoor; Installation of a LAF system with HEPA filters vs. natural ventilation	Airborne fungal concentration Invasive pulmonary aspergillosis (IPA) infection	cfu/m3, ratio of concentration indoor/outdoor (microbiology analysis of air samples); Number of IPA cases	Before-after study	During construction, aspergillus spore concentration in the BMT unit (133cfu/m3) far exceeded (a ratio of 11:1) those measured in outdoor while the spore counts in other units were consistent lower than outdoor. Installation of LAF w/HEPA virtually eliminated aspergillus spore. Six of 19 children in BMT unit during construction work died of IPA. No cases of IPA were documented after the installation LAF/HEPA.	A bone marrow transplantation unit	38 children undergoing bone marrow transplant (19 before and 19 after LAF/HEPA installation)
Beggs, C. B., Kerr, K. G., Noakes, C. J., Hathway, E. A., & Sleight, P. A. (2008). The ventilation of multiple-bed hospital wards: Review and analysis. <i>American Journal of Infection Control</i> , 36 (4), 250-259.	Ventilation strategy (location of ventilation grilles)	Ceiling vs. wall (low-high, and high low)	Bioaerosol concentration (volume average)	cfu/m3 (Computational fluid dynamics [CFD] study)	Experiment using simulation software	Bioaerosol concentration was lower in ceiling ventilation (2467 cfu/m3) than wall ventilation (12487 and 10601 cfu/m3)	An empty 32-m3 room	NA
Ben-Abraham, R., Keller, N., Szold, O., Vardi, A., Weinberg, M., Barzilay, Z., & Paret, G. (2002). Do isolation rooms reduce the rate of nosocomial infections in the pediatric intensive care unit? <i>Journal of Critical Care</i> , 17 (3), 176-180.	Single rooms with separated sinks	Conversion of a open bay unit to single room unit with separated sinks	Nosocomial infection rate; Patient length of stay	# of hospital-acquired infections per patient (infection surveillance); # of days (medical records)	Before-after	Both hospital -acquired infections and the patient length of stay were significantly reduced when the unit was converted from open bay to single rooms with separate sinks.	A six-bed pediatric intensive care unit in Israel	About 200 patients hospitalized for more than 48 hours
Bergeron, V., Reboux, G., Poirot, J.L., & Laudinet, N. (2007). Decreasing airborne contamination levels in high-risk hospital areas using a novel mobile air-treatment unit. <i>Infection Control and Hospital Epidemiology</i> , 28 (10), 1181-1186.	Mobile air-treatment unit that uses nonthermal-plasma reactors	Air treatment unit on vs. off; Patient room w/ the air treatment unit vs. patient room w/o the unit	Particulate level (all particles >0.5 um); Bioaerosol concentration (fungal flora, mesophilic flora)	Particles/m3 (air Sampling using particle counter); cfu/m3 (air sampling using biocollector and biology analysis)	Quasi-experiment	The air-treatment unit significantly reduced the time (from 12 minutes to 2 minutes) to lower airborne particles by 90% and reduced airborne fungus levels (75%- 80%).	Two hospitals in France	An operating room and two Hematology patient rooms
Carling, P. C., Briggs, J. L., Perkins, J., & Highlander, D. (2006). Improved cleaning of patient rooms using a new targeting method. <i>Clinical Infectious Diseases</i> , 42 (3), 385-388.	A new method of identifying high touched objects (HTOs) that are poorly cleaned; Multidisciplinary educational intervention	Before and after the intervention	Cleaning of HTOs	Percentage of HTOs cleaned after 2-3 terminal cleanings (HTOs marked with targeting solutions which fluoresces under black light)	Before-after	Sinks, toilet tops, and tray tables had high rates of cleaning (85%-92%); bedpan cleaning equipment, toilet handholds, door knobs were least cleaned (12%-17%). After the educational program, the rates of cleaning improved.	Three hospitals	1404 HTOs in 157 rooms before the intervention, 744 HTOs in 98 rooms after the intervention
Carling, P. C., Parry, M. F. & Von Beheren, S. M. (2008). Identifying opportunities to enhance environmental cleaning in 23 acute care hospitals. <i>Infection control and hospital epidemiology</i> , 29 (1), 1-7.	Environmental surface type	High-risk object categories (e.g. sink, door knob, toilet seat)	Thoroughness of terminal cleaning	Percentage of objects cleaned after terminal cleanings (objects marked with targeting solutions which fluoresces under black light)	Observational	Overall, 49% of evaluated surfaces were cleaned after terminal cleanings. Some objects (e.g. sink, toilet seat, tray table) tended to better cleaned than other objects (e.g. toilet handhold, bedpan cleaner, light switch, door knob)	23 hospitals	13,369 high-risk objects in 1119 patient rooms/bathrooms
Chang, V. T., & Nelson, K. (2000). The role of physical proximity in nosocomial diarrhea. <i>Clinical Infectious Diseases</i> , 31 (3), 717-722.	Physical proximity	Whether or not a patient was roommate or neighbor of another patient with diarrhea, or stayed in room after the patient with diarrhea left (mapping of patient rooms)	Nosocomial acquisition of <i>Clostridium difficile</i> associated diarrhea (CDAD) and antibiotic-associated diarrhea (AAD)	Whether a patient had nosocomial CDAD and AAD (clinical records)	Observational, regression analysis	Physical proximity is an independent risk factor for acquisition of nosocomial CDAD and AAD.	A 305-bed community hospital	2859 patients who stayed > 2 days

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Cohen, B., Saiman, L., Cimiotti, J., & Larson, E. (2003). Factors associated with hand hygiene practices in two neonatal intensive care units. <i>Pediatric Infectious Disease Journal</i> , 22 (6), 494-499.	Hand hygiene device	Alcohol-based hand rub dispenser vs. antimicrobial soap and sink	Hand hygiene compliance	# of hand touches with new gloves/cleaned hands, used gloves, and no gloves/uncleaned hands per neonate per shift	Quasi-experiment, comparison of two units using different hand hygiene devices	Staff members in the NICU using alcohol-based hand rub dispenser were more likely to use new gloves/cleaned hands to directly touch neonates than staff in the NICU using antimicrobial soap and sinks.	Two NICU's (44 and 50 beds) in New York City	1,472 hand touches by staff members
Crimi, P., Argellati, F., Macrina, G., Tinteri, C., Copello, L., Rebor, D., . . . Rizzetto, R. (2006). Microbiological surveillance of hospital ventilation systems in departments at high risk of nosocomial infections. <i>Journal of Preventive Medicine and Hygiene</i> , 47 (3), 105-109.	Location of HEPA filters in the HVAC system; Ventilation type	Central (inside main air ducts) vs. peripheral (at the openings of ducts); Natural ventilation vs. mechanical ventilation	Air contamination of bacteria, Aspergillus	Percentage of positive samples; cfu/m3 (air sampling, incubation)	Observational	Hospital departments with central HEPA filters had higher level of air contamination than the departments with peripheral HEPA filters. Lower levels of air contamination were recorded in spaces with mechanical ventilation.	Seven departments in an Italian hospital	About 310 air samples
Escombe, A. R., Oeser, C. C., Gilman, R. H., Navincopa, M., Ticona, E., Pan, W., et al. (2007). Natural ventilation for the prevention of airborne contagion. <i>PLoS Medicine</i> , 4 (2), e68.	Ventilation type; Environmental factors influencing natural ventilation	Natural ventilation vs. mechanical ventilation; Area of windows/doors open (m2) Placement of windows/doors on opposite walls Ceiling height (m) Floor area (m2) Wind speed (km/h)	Ventilation rate; Estimated risk of airborne Tuberculosis (TB) infection	Air changes per hour (ACH, measured by tracer gas concentration decay technique) Absolute ventilation rate (m3/h) Percentage of susceptible patients infected, estimated by Wells-Riley model of airborne infection	Experiment	Natural ventilation by opening windows/doors provided a median of 28 ACH, compared to 12 ACH designed for (< 6 ACH actually delivered by) mechanically ventilated isolation rooms. Older rooms with higher ceilings and bigger windows had higher ventilation rates (40 ACH). The risk of TB infection was lower in naturally ventilated rooms.	Eight hospitals in Lima, Peru	70 clinical rooms with natural ventilation, 12 isolation rooms with mechanical ventilation
Gardner, P. S., Court, S. D., Brocklebank, J. T., Downham, M. A., & Weightman, D. (1973). Virus cross-infection in paediatric wards. <i>British Medical Journal</i> , 2 (5866), 571-575.	Single room	Single room unit vs. open unit (percentage of beds in single rooms <40% vs. >85%)	Rate of virus cross-infection for respiratory syncytial infection, influenza A, parainfluenza	Cross-infection per million susceptible days per infective day	Quasi-experiment, comparison of four single room units and four open units	Cross infection rates were significantly lower in single room units than in open units.	8 pediatric units in UK	8 pediatric units
Gustafson, T. L., Lavelly, G. B., Brawner, E. R., Jr., Hutcheson, R. H., Jr., Wright, P. F., & Schaffner, W. (1982). An outbreak of airborne nosocomial varicella. <i>Pediatrics</i> , 70 (4), 550-556.	Air flow pattern	Air flowing from the positive-pressure isolation room where a patient with varicella stayed (air flow pattern identified using tracer gas study)	Concentration of viral particles in corridors; Rate of Varicella transmission	Relative concentration compared to the level in index patient room (% estimated by tracer gas study) Percentage (# patients who contracted varicella/total patients)	Observational	Air flowed from the positive-pressure isolation room to corridor. The tracer gas released in the room achieved significant concentration in corridor. Patients who were closer to the isolation room had significantly higher risk of varicella transmission. Patients who entered corridor zone with higher concentration of viral particles (estimated by tracer gas study) were more likely to contract varicella.	A pediatric unit	70 patients potentially susceptible to varicella
Hahn, T., Cummings, K. M., Michalek, A. M., Lipman, B. J., Segal, B. H., & McCarthy, P. L., Jr. (2002). Efficacy of high-efficiency particulate air filtration in preventing aspergillosis in immunocompromised patients with hematologic malignancies. <i>Infection Control and Hospital Epidemiology</i> , 23 (9), 525-531.	High-efficiency particulate air (HEPA) filters; Laminar air flow (LAF)	One unit wing w/ HEPA filters (including some rooms w/ LAF) vs. another wing w/o HEPA/LAF; Before and after the installation of HEPA filters in the later wing	Aspergillus concentration Aspergillosis infection	cfu/m3 (air samples) Number of Aspergillosis cases	Before-after study	Higher Aspergillus conidia count (>150 cfu/m ³) in the wing w/o HEPA/LAF than the wing w/ HEPA and LAF(<4 cfu/m ³). There were fewer infections of invasive aspergillosis in the wing with HEPA/LAF. The infection rate in the wing without HEPA/LAF was reduced after the installation of HEPA and other infection control measures.	A hematologic oncology unit	91 immunocompromised patients who stayed more than 4 days
Harris, D., Pacheco, A., & Lindner, A. S. (2010). Detecting potential pathogens on hospital surfaces: An assessment of carpet tile flooring in the hospital patient environment. <i>Indoor and Built Environment</i> , 19 (2), 239-249.	Flooring material	Types of flooring material (tiled and non-tiled carpet, vinyl)	Surface contamination	Bacterial community composition (bacteria types identified by swab sampling and generic analysis - denaturing gradient gel electrophoresis)	Observational	Bacterial diversity (number of genera identified) was higher in the edges of tiled carpets than the surface and backing. Vinyl floor samples exhibited a lower number of genera but higher numbers of bacterial genus/species associated with genera of pathogenic bacteria. Various surfaces (e.g. shoe sole, medical monitor, laundry cart) carried unique bacterial species and might potentially transmit disease.	Medical units in a Midwest community hospital	Swab samples in 12 locations (9 samples for each of the 6 tiled carpet locations) in each of 5 sampling visits

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Hutton, M. D., Stead, W. W., Cauthen, G. M., Bloch, A. B., & Ewing, W. M. (1990). Nosocomial transmission of tuberculosis associated with a draining abscess. <i>Journal of Infectious Diseases</i> , 161 (2), 286-295.	Air flow pattern; Exposure to the patient	Air flowing from the positive-pressure isolation room where a patient with a large tuberculous abscess stayed to other areas (air flow pattern identified using a aerosol dispersion study); Exposure to patient recalled by healthcare workers	Tuberculin conversion in healthcare workers; Tuberculin reactivity in visitors and patients (for whom the previous reactivity status was unknown)	# of healthcare workers w/ vs. w/o Tuberculin conversion (skin test, induration of 10 mm or greater with an increase of at least 6mm more than 1 year after a negative result (<10 mm); A reactor was a person whose current tuberculin test was >=10mm.	Observational	Exposure to the patient with Tuberculous infection was associated with increased risk of Tuberculin conversion and reactivity. Air flow from the positive pressure room where a patient with a large tuberculous abscess stayed was a strong factor contributing to high risk of Tuberculosis transmission. Patients and visitors closer to the positive pressure room had higher risk of Tuberculin reactivity.	A 250-bed hospital in rural Arkansas	442 employees and 50 students
Jiang, S. P., Huang, L. W., Chen, X. L., Wang, J. F., Wu, W., Yin, S. M., . . . Huang, Z. (2003). Ventilation of wards and nosocomial outbreak of severe acute respiratory syndrome among healthcare workers. <i>Chinese Medical Journal</i> , 116 (9), 1293-1297.	Natural ventilation window size	Ventilation window area/room volume (m2/m3)	Severe acute respiratory syndrome (SARS) infection rate	Percentage of healthcare workers infected with SARS	Observational	The percentage of healthcare workers infected with SRAS appeared to be negatively associated with the ratio of ventilation window area to room volume.	SARS wards in a Chinese hospital	About 430 healthcare workers in four wards
Kaplan, L. M., & McGuckin, M. (1986). Increasing handwashing compliance with more accessible sinks. <i>Infection Control</i> , 7 (8), 408-410.	Number of accessible handwashing sinks	Bed-to-sink ratio (1:1 vs. 4:1)	Hand-washing compliance rate	Percentage of direct contacts with patients and their support equipment followed by handwashing (observation)	Quasi-experimental	Nurses in the unit with lower bed-to-sink ratio had significantly higher handwashing compliance (76%) rate than those in the unit with fewer sinks (51%).	A open medical ICU (bed: sink = 1:1) and a open surgical unit (bed: sink = 4:1)	30 nurses, 8 physicians, and 4 technicians
Lankford, M. G., Collins, S., Youngberg, L., Rooney, D. M., Warren, J. R., & Noskin, G. A. (2006). Assessment of materials commonly utilized in health care: Implications for bacterial survival and transmission. <i>American Journal of Infection Control</i> , 34 (5), 258-263.	Interior finish materials; Surface decontamination	Upholstery (4), flooring (6), wall finishes (4); Before and after decontamination according to manufacturer recommendations	Bacterial growth (vancomycin-resistant enterococci [VRE] and Pseudomonas aeruginosa [PSAE])	Confluent growth (CG, bacterial growth so heavy that individual colonies are not recognized for counting), no confluent growth (NCG, 1-388 cfu's), no growth (NG)	Experiment	Vinyl composition tile, microvented perforated vinyl wall covering, and paper-backed wall covering had higher VRE growth than other materials including synthetic or vinyl-backed carpet. .	Hospital	14 interior materials
Larson, E. L., Albrecht, S., & O'Keefe, M. (2005). Hand hygiene behavior in a pediatric emergency department and a pediatric intensive care unit: Comparison of use of 2 dispenser systems. <i>American Journal of Critical Care</i> , 14 (4), 304-311.	Alcohol-based hand rub dispenser type	Manual operated dispenser vs. battery-operated, touch-free dispenser	Dispenser use frequency; Hand hygiene frequency	# of uses per dispenser per day (electronic counter); # of incidences of hand hygiene per patient per hour (observation); # of incidences of hand hygiene before patient contact per hour (observation)	Quasi-experiment, crossover design	The touch-free dispenser was used significantly more frequently than the manual dispenser.	ED and PICU at a large pediatric hospital	About 300 hours of observation in 4 months
Lutz, B. D. J., Rinaldi, J., Wickes, M. G., Huycke, B.L., Mark M. (2003). Outbreak of invasive Aspergillus infection in surgical patients, associated with a contaminated air-handling system. <i>Clinical Infectious Diseases</i> , 37 (6), 786-793.	HVAC system moisture and contamination; HVAC system maintenance (removing insulating materials and coating surfaces contaminated with fungicide)	Environmental inspection; Implementation of the maintenance	Air contamination; Invasive Aspergillus infection	# of particles > 3 u m (particle counter); # of invasive Aspergillus infection cases (hospital medical records)	Before-after; observational	Dampness and contamination of Aspergillus found in HVAC ductwork. 3-1000-fold increase in particle concentrations in operating rooms and hallways than in ductwork immediately downstream of air-handling system. After HVAC renovation, airborne particles reduced and no new invasive Aspergillus case was identified.	One operating room and related HVAC system	6 cases of Invasive Aspergillus, air samples, air duct material specimen
MacKenzie, F. M., Bruce, J., Struelens, M. J., Goossens, H., Mollison, J., & Gould, I. M. (2007). Antimicrobial drug use and infection control practices associated with the prevalence of methicillin-resistant Staphylococcus aureus in European hospitals. <i>Clinical Microbiology and Infection</i> , 13 (3), 269-276.	Environmental infection control measures: -Single room isolation -Hand hygiene device(alcohol-based hand solutions)	Yes/No response to postal and online questionnaire questions	MRSA prevalence rate (hospital level)	Percentage of clinical S. aureus isolates that were methicillin-resistant, collected by questionnaire	Observational, retrospective, cross-sectional study	Data strongly indicted that certain environmental control measures, alcohol-based solutions for hand hygiene and single rooms of isolating infected patients, were associated with lower MRSA prevalence rates.	Hospitals across various Europe regions	173 European hospitals

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
McDevitt, J. J., Milton, D. K., Rudnick, S. N., & First, M. W. (2008). Inactivation of poxviruses by upper-room UVC light in a simulated hospital room environment. <i>PLoS ONE</i> , 3 (9), e3186.	Upper-room air ultraviolet germicidal irradiation (UVGI); Environmental factors influencing UVGI effectiveness	Upper-room UVGI on/off; Mechanical air mixing (ceiling fan); Convection (heat box); Relative humidity (%)	Equivalent air changes per hour due to UVGI	The amount of virus-free dilution air that would be needed to provide the same reduction of virus concentration that was actually measured (ptu/m3)	Experiment	Upper room UVGI produced decreases in airborne virus concentration equivalent to 18 and more air changes per hour. UVGI was more effective (i.e. more equivalent ACH) at low relative humidity in room with efficient air mixing.	A simulated hospital room	NA
McManus, A. T., Mason, A. D., Jr., McManus, W. F., & Pruitt, B. A., Jr. (1992). Control of pseudomonas aeruginosa infections in burned patients. <i>Surgical Research Communications</i> , 12, 61-67.	Single room	Single room unit vs. open unit	Frequency of colonization; Time delay in colonization; Expected mortality	Percentage of patients colonized; Postburn day of colonization; Estimated using an equation based on burn size and age	Before-after; retrospective;	The single room unit had a more delayed postburn day of colonization of Pseudomonas aeruginosa (PA). The single room unit had a lower frequency and a more delayed postburn day of colonization of Pseudomonas bacteremia, pneumonia, and invasive burn-wound infection.	An Army burn center	2,316 burn patients admitted in the open ward (1980-1983) or the single-room unit (1984-1990)
Menzies, D., Fanning, A., Yuan, & Fitzgerald, M. (2000). Hospital ventilation of risk for tuberculosis infection in Canadian health care works. <i>Annals of Internal Medicine</i> , 133 (10), 779-789.	Ventilation rate	Air changes per hour (tracer gas technique)	Tuberculin conversion in healthcare workers	# of healthcare workers w/ vs. w/o Tuberculin conversion (skin test, induration of 10 mm or greater with an increase of at least 6mm more than 1 year after a negative result (<10 mm)	Observational	Higher air changes per hour was associated with fewer healthcare workers with Tuberculin conversion.	17 Canadian acute-care hospitals	About 1300 healthcare workers who had two skin tests more than 1 year apart at the same hospital and was Tuberculin negative at the first test
Menzies, D., Popa, J., Hanley, J.A., Rand, T., & Milton, D. K. (2003). Effect of ultraviolet germicidal lights installed in office ventilation systems on workers' health and well-being: Double-blind, multiple crossover trial. <i>Lancet</i> , 362 (9398), 1785-1790.	Ultraviolet germicidal irradiation (UVGI) in ventilation system	UVGI (on vs. off)	Work-related symptom (systemic, mucosal, respiratory, musculo-skeletal) Thermal condition Chemical concentration Viable microbial concentration Endotoxin concentration	Questionnaire surveys; Mean temperature (C), relative humidity (%), air velocity (m/sec), HVAC recirculation (%); CO2 (ppm), TVOCs (mcg/m3), formaldehyde (ppm), ozone (ppb), nitrogen oxides (ucg/m3); Fungi (cfu/m3), bacteria (cfu/m3); Endotoxin (eu/m3, eu/coupon)	Quasi-experiment, repeated measurement	UVGI was associated with significant reduction of microbial and endotoxin concentrations on irradiated surfaces in the ventilation system. The use of UVGI resulted in fewer work-related symptoms.	Three office buildings in Canada, with sealed windows and mechanical ventilation	771 office workers
Modol, J., Sabria, M., Reynaga, E., Pedro-Botet, M. L., Sopena, N., Tudela, P., . . . Rey-Joly, C. (2007). Hospital-acquired legionnaires disease in a university hospital: impact of the copper-silver ionization system. <i>Clinical Infectious Diseases</i> , 44 (2), 263-265.	Water disinfection system: copper-silver ionization system; Cooper/silver levels	The installation of the copper-silver ionization system; Colorimetric analysis (optimal level 0.2-0.5mg/L), atomic adsorption (0.02-0.05 mg/L)	Environmental colonization of <i>Legionella</i> ; Rate of hospital-acquired legionnaires diseases (HALD) (physician evaluation according to CDC criteria,	# of samples tested positive for <i>L. pneumophila</i> , colony-forming unit (CFU)/L (water samples seeded in selective modified Wadowsky Yee-buffered charcoal yeast extract-α agar); # of cases per 1000 patient discharges (physician evaluation according to CDC criteria based on test results of respiratory, serum, or urinary samples)	Longitudinal study (repeated measurements) Period 1 (Jan 1998 - Sept. 199) Period 2 (Oct 1999 - Dec. 2004)	The installation of the copper-silver ionization system significantly reduced colonization of in water samples, and reduced infection rate of HALD, from 2.45 to 0.18 cases per 1000 patient discharge.	A 630-bed hospital in Spain	About 410 water samples, 82 HALD cases in period 1 and 20 in period 2
Noskin, G. A., Bednarz, P., Suriano, T., Reiner, S., & Peterson, L. (2000). Persistent contamination of fabric-covered furniture by Vancomycin-resistant Enterocci: Implication for upholstery selection in hospitals. <i>American Journal of Infection Control</i> , 28 (4), 311-313.	Furniture cover materials	Fabric vs. vinyl	Contamination of vancomycin-resistant <i>Enterocci</i> (VRE); Disinfection of VRE	Presence or absence of VRE (after inoculation, and after cleaning with a quaternary ammonium germicide in simulated inoculation studies)	Simulated experiment	VRE was found at 72 hours and seven days after inoculation on fabric and vinyl upholstered chairs. Routine disinfection was successful in removing VRE from vinyl surfaces but not from fabric surfaces.	A 688-bed hospital in Chicago	10 seat cushions in five randomly chosen hospital rooms; five simulated samples
Swoboda, S. M., Earsing, K., Strauss, K., Lane, S., & Lipsett, P. A. (2004). Electronic monitoring and voice prompts improve hand hygiene and decrease nosocomial infections in an intermediate care unit. <i>Critical Care Medicine</i> , 32 (2), 358-363.	Automatic computerized reminders for failure to perform hand hygiene on room exit.	Electronic system including electronic beam breakers or motion detectors placed at the threshold of each room to monitor entry and exit of personnel; A computerized reminding system that gave prerecorded audio/visual messages instructing personnel to wash their hands if they had not done so before exiting the room or within	Hand hygiene compliance Nosocomial infection rate	Electronic monitoring of entry and exit of personnel and the use of hand hygiene devices (percentage - actual hand hygiene divided by hand hygiene opportunities); Observation; # of NI's per 100 admits, # of NI's per 1000 patient days (clinical records, assessed by a review committee of physicians and nurse)	Quasi-experiment, repeated measurements	The hand hygiene compliance improved and the nosocomial infection rate decreased after the installation of automatic reminding device. Electronic monitoring underestimated hand hygiene compliance.	A 14-bed intermediate care unit in a university hospital	1875 patients admitted to the unit, 283,488 electronically monitored entries into a patient room

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Takai, K., Ohtsuka, T., Senda, Y., Nakao, M., Yamamoto, K., Matsuoka, J., & Hirai, Y. (2002). Antibacterial properties of antimicrobial-finished textile products. <i>Microbiology and immunology</i> , 46 (2), 75-81.	Antimicrobial-finished textile product (AFTPs)	Five AFTPs treated with antibacterial agents and one control product that is untreated	Bacteria contamination	Viable cell ratio (%)	Experiment	Textile materials containing Ag, Zn, Ammonium Zeolite and chitosan, to various extent, limited the growth of some bacterial species and strains. Organic matter and water content could affect the antibacterial effectiveness in clinical setting.	A lab	Samples of 5 AFTPs and one control material
Williams, H. N., Singh, R., & Romberg, E. (2003). Surface contamination in the dental operatory: A comparison over two decades. <i>Journal of the American Dental Association</i> , 134 (3), 325-330.	Environmental improvements: -reduce the number of surface areas -mobile countertops -central sterilization facility -autoclavable handpieces -foot-pedal controlled sinks	Before and after the environmental improvements	Surface contamination (light handle covers, jacket cuffs, sinks and floors)	Bacteria counts (colony-forming unit)	Before-after	A lower level of surface bacterial contamination was found after the environmental improvements together with stringent infection control procedures.	A large (>200-chair) dental clinic in Maryland	30 randomly selected dental operatories
Xu, P., Kujundzic, E., Peccia, J., Schafer, M. P., Moss, G., Hernandez, M., & Miller, S.L. (2005). Impact of environmental factors on efficacy of upper-room air ultraviolet germicidal irradiation for inactivating airborne mycobacteria. <i>Environmental Science & Technology</i> , 39 (24), 9656-9664.	Environmental factors influencing UVGI effectiveness	Air mixing (on/off); Relative humidity (%)	Ultraviolet germicidal irradiation (UVGI) inactivation rate; UVGI effectiveness	The rate at which UVGI inactivates microorganism over time in decay test condition (1/h); Percentage of bacteria concentration reduction (cfu/m3) due to UVGI in constant generation condition (Air sampling, culture, epifluorescent microscopy)	Experiment	UVGI inactivation rate was significantly higher in mixing condition than in non mixing condition. UVGI inactivation rate and effectiveness decreased significantly when relative humidity increased.	A simulated hospital room	NA

Healthcare-Associated Infections: Matrix of relationships

		Outcome						
	Variable	Air contamination	Inanimate surface contamination	Water contamination	Hand hygiene	Healthcare-associated infection	Length of stay	Mortality
Environmental feature	Patient room occupancy							
	Physical proximity							
	Air pressure difference between adjacent spaces							
	Laminar air flow							
	Location of ventilation grilles							
	Ventilation system type							
	Ventilation rate							
	Environmental factors influencing natural ventilation							
	High-efficiency particulate air (HEPA) filter							
	Mobile air-treatment unit							
	Ultraviolet germicidal irradiation							
	HVAC system maintenance							
	Construction work							
	Interior finish material							
	Furniture covering material							
	Antimicrobial-finished textile product							
	Surface cleaning							
	Number of hand hygiene device							
	Alcohol-based hand rub							
	Automatic computerized reminder of hand hygiene							
Copper-silver ionization								

Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

Medical errors: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environment feature	Acuity-adaptable room	Rooms designed with sufficient space and provision for equipment, medical gases, and power to accommodate any level of patient acuity (Evans, Pati, & Harvey, 2008).	Yes/no, before/after (Hendrich, Fay, & Sorrells, 2004)	Design manipulation - The coronary critical care unit and medical step-down unit were redesigned and combined into one acuity-adaptable unit (Hendrich, Fay, & Sorrells, 2004).
	Barcode-assisted dispensing system	A medication dispensing system that uses barcodes to ensure that the correct medication, in its correct dose and formulation, is being dispensed (Poon et al., 2006). A patient is identified by a barcode. The barcode of every drug is scanned and checked against the information in electronic medication administration records before administration. When a wrong drug or wrong patient is scanned, a computer signal pops up and the process is stopped until the right patient or drug is identified (Ros & de Vreeze-Wesselink, 2009).	- Yes/no, before/after (Poon et al., 2006).	Design manipulation - A dedicated repacking center (for affixing a barcode onto each medication if the manufacturer had not already done so) was built to implement a barcode-assisted dispensing system in 3 configurations. In 2 configurations, all doses were scanned once during the dispensing process. In the third configuration, only 1 of several doses of the same medication being dispensed was scanned (Poon et al., 2006).
	Bedside assortment picking (BAP) trolley	A new type of drug trolley with separate compartments for ward-specific stock and patient-specific medicines. Equipped with a wireless laptop that connects to electronic medication administration records and guides the nurse to the correct location of a drug (Ros & de Vreeze-Wesselink, 2009).	- Yes/no, before/after (Ros & de Vreeze-Wesselink, 2009).	Design manipulation - A new type of drug trolley - bedside assortment picking trolley - was developed and introduced to replace a conventional trolley (Ros & de Vreeze-Wesselink, 2009).
	Computerized physician order entry (CPOE)	Computer-based systems for automating the medication ordering process. A basic CPOE ensures standardized, legible, complete orders by accepting only those orders that are typed and in a standard and complete format (Kaushal & Bates, 2001).	- Yes/no, before/after (King et al., 2003)	Design manipulation - A commercially available CPOE system developed by Eclipsys was implemented in two inpatient wards. The CPOE system was originally introduced as Carevision, underwent periodic product upgrades, and is now commercially available as Sunrise Clinical Manager (King et al., 2003).
	Daylight	Light originating from the sun that reaches Earth's surface after reflecting off the sky's vault (Zunde & Bougdah, 2006)	- Average hours of daylight/darkness for each month (Booker & Roseman, 1995)	Existing data - Existing data from public weather service (Booker & Roseman, 1995)

	Term	Definition	Metrics	Measurement method
	Distraction	An external stimulus causing observable responses from healthcare workers without disrupting the ongoing, productive activity (Flynn et al., 1999).	<ul style="list-style-type: none"> - Distraction condition versus non-distraction condition (Plyuter et al., 2010); - Number of distractions per pharmacist per half hour (Flynn et al., 1999).; 	<p>Experimental manipulation</p> <ul style="list-style-type: none"> - In one experimental condition, subjects listened to popular songs combined with social conversation irrelevant to the surgical task and non-optimal laparoscope navigation (Plyuter et al., 2010). <p>Video recording of actual working</p> <ul style="list-style-type: none"> - Two video cameras recorded prescription-filling operations from two different angles throughout each eight-hour study day. The videotapes were reviewed simultaneously to record time of interruption or distraction, prescription-filling task affected, type of interruption or distraction, reason for the interruption or distraction, and study participant affected (Flynn et al., 1999).
	Illumination level (illuminance)	The intensity of luminous flux (Stein, 1997).	<ul style="list-style-type: none"> - Lux (1 lux=1 lumen/m²) - Foot-candle (1 ftc = 10.764 lux) (Buchanan et al., 1991) 	<p>Photometer</p> <ul style="list-style-type: none"> - Photometer (model IL1350, serial 2048, International Light Inc., Newburyport, MA) with an illuminance sensor (model SCD110, serial 1366, International light). Eight measurements were taken, starting 6 inches from the end of the conveyor belt and every 12 inches thereafter. The amount of illumination represents the mean of the eight measurements taken daily for seven days (Buchanan et al., 1991).
	Interruption	Cessation of productive activity before completing a prescription-filling task, due to any externally imposed, observable, or audible reason. Interruptions can be caused by staff looking at people passing through the ambulatory care pharmacy and related to prescription-processing questions (Flynn et al., 1999). Situation in which a nurse ceased a medication preparation or administration task in order to attend to an external stimulus (Westbrook et al., 2010).	<ul style="list-style-type: none"> - Number of interruptions per pharmacist per half hour (Flynn et al., 1999); - Number of interruptions during one medication administration (Westbrook et al., 2010). 	<p>Video recording</p> <ul style="list-style-type: none"> - See "distraction" <p>Observation</p> <ul style="list-style-type: none"> - Observers (registered nurses and physicians) used a structured observational tool on a PDA to record number of interruptions that a nurse experienced (Westbrook et al., 2010).
	Light fixture (luminaire)	A complete lighting unit consisting of a light source (one or more lamps), and the parts designed to position the light source and connect it to the power supply. Parts for protecting the light source or ballast and for distributing the light may be included (National Fire Protection Association, 2010)	<ul style="list-style-type: none"> - Different lighting conditions determined by supplemental lighting fixtures and color filters (Buchanan et al., 1991). 	<p>Design manipulation</p> <ul style="list-style-type: none"> - The installation of supplemental light fixtures and the removal of color filters (Buchanan et al., 1991).

	Term	Definition	Metrics	Measurement method
	Noise	Auditory stimulus, such as a change in loudness, bearing no informational relationship to the presence or completion of the task. Sound: a change in loudness bearing some informational relationship with the task at hand (Flynn et al., 1996).	<ul style="list-style-type: none"> - Number of unpredictable/controllable/uncontrollable sounds per minute; - Equivalent sound level (Leq) per half hour (Flynn et al., 1996). 	<p>Videotape recording</p> <ul style="list-style-type: none"> - Two video cameras placed in inconspicuous locations recorded ambient sounds. The videotapes were synchronized with the time that each patient's prescription set was being filled in order to determine which sounds affected performance (Flynn et al., 1996). <p>Noise-logging dosimeter</p> <ul style="list-style-type: none"> - Sound levels were continuously recorded in decibels (A scale) by a noise-logging dosimeter (Quest Electronics Noise-Logging Dosimeter, model M28-12) located at a 70 degree angle above the main prescription-filling area; the Leq was calculated for each half hour using the methods described by Taylor & Lipscomb (1978) for analyzing decibel levels that change over time (Flynn et al., 1996).
	Physical configuration of drug stock shelves	Spatial arrangement of drug items including the amount of space between drug items on shelves (Flynn et al., 2002).	- Separation and space between items versus tightly packed items on shelves (Flynn et al., 2002).	Environmental inspection
Outcome	Adverse drug event (ADE)	Harm caused by a drug or the use of a drug (Nebeker, Barach, & Samore, 2004). Potential drug event defined as dispensing errors that can harm patients if not intercepted before medication administration (Poon et al., 2006).	<ul style="list-style-type: none"> - Number of ADEs per 1,000 patient days; - Percentage of prescriptions involved in potential ADEs divided by the total number of prescriptions (King et al., 2003; Poon et al., 2006) 	<p>Physician review of error reports</p> <ul style="list-style-type: none"> - Two physicians accessed the medication error database and reviewed all original incident reports. Severity was reclassified based on patient impact as an ADE, potential ADE, or other (King et al., 2003). - Each of two board-certified internists independently reviewed and rated the severity of each dispensing error by using an explicit set of criteria. Each physician-reviewer determined whether the patient could have had an injury if the dispensing error had reached the patient, defined errors that could harm patients as potential ADEs, and classified potential ADEs as significant, serious, and life-threatening (Poon et al., 2006).

	Term	Definition	Metrics	Measurement method
	Medication administration procedural failure	Failure to comply with specific medication administration procedures, including failure to read a medication label, failure to check patient's identification, temporary storage of medication in an unsecured environment, failure to record on a medication chart, use of a nonaseptic technique, failure to check pulse/blood pressure/blood glucose level (when applicable), failure of 2 nurses to check preparation of a dangerous drug or IV medication (Moorthy et al., 2003).	- Percentage of medications with procedural failures (Westbrook et al., 2010).	Direct observation - Observers (registered nurses and physicians) used a structured observational tool on a PDA to record nursing procedures related to medication administration (Westbrook et al., 2010).
	Medication error	Error that occurs while ordering, transcribing, dispensing, administering, or monitoring medications, irrespective of the outcome (Kaushal & Bates, 2001).	<ul style="list-style-type: none"> - Number of dispensing errors per pharmacist per hour (Flynn et al., 1999); - Percentage of prescriptions involved in errors divided by the total number of prescriptions (Buchanan et al., 1991; ; Flynn et al., 1999; Westbrook et al., 2010). - Number of nurse medication errors per month (Booker & Roseman, 1995). - Severity of error: five severity rating levels (1 - little or no effect on patient, 2 - likely to lead to increase in level of care, 3 - likely to lead to permanent reduction in bodily functioning, 4 - likely to lead to a major permanent loss of function, 5 - likely to lead to death); two categories (major errors - levels 4-5, minor errors - levels 1-3) (Westbrook et al., 2010). 	Direct observation & expert evaluation <ul style="list-style-type: none"> - Filled prescriptions evaluated by researcher to detect deviations from physician's orders (Flynn et al., 1999; Flynn et al., 2002) - After the routine final check by a pharmacist but before the drug was dispensed to the patient, every prescription was reviewed for content by the observer (Buchanan et al., 1991) - A trained research pharmacist-observer inspected the medications that had already undergone the usual 3-step dispensing process to look for dispensing errors and classify the error types (Poon et al., 2006) - The direct observation method consists of an observer witnessing the administration of medicines to patients by the nurse. The observer checks the administration of each dose by the nurse with the help of an exact copy of the medication administration record. The observer does not interfere if an error is observed. If the observer estimated that the patient's safety is compromised, a warning is given to the nurse before the medicine is actually taken by the patient (Ros & de Vreeze-Wesselink, 2009). - Observers (registered nurses and physicians) used a structured observational tool on a PDA to record details of medication administered and compare the data with patients' medication charts to determine whether the medication administered differed from what was ordered (Westbrook et al., 2010).

	Term	Definition	Metrics	Measurement method
				<p>Adverse event reporting system</p> <ul style="list-style-type: none"> - A passive reporting system. The nurse and physician involved in a medication error complete an incident report and document the incident. The severity of patient harm is rated as none, mild, moderate, or severe. Medication errors are then sent to the pharmacy department and entered into a spreadsheet database (King et al., 2003). - The annual medication error index was measured by the hospital's standard system for reporting adverse events (Hendrich, Fay, & Sorrells, 2004). - Errors were documented on a standard error reporting form completed by the nurse committing the error and/or staff discovering the error (Booker & Roseman, 1995).
	Surgical errors	Errors in the performance of surgical procedures. In a laparoscopic task, skill-based errors involved dropped objects and objects placed inaccurately in the disc-- either on their side or incompletely within the zone; knowledge-based errors occurred when objects were placed in the wrong zone (Moorthy et al., 2003).	- Number of errors in a surgical task (task error score) (Moorthy et al., 2003; Pluyter et al., 2010)	<p>Surgery simulation system</p> <ul style="list-style-type: none"> - Xitact LC 3.0 virtual reality simulator (Xitact SA, Morges, Switzerland). The clip and cut assessed (CCA) task in the Clip and Cut (C&C) module was used. Task errors were recorded by the simulator (Pluyter et al., 2010).
	Transport, patient intra-hospital transport	Transport of patients within the hospital (Ulrich & Zhu, 2007)	- Number of patient transports between nursing units /month (Hendrich, Fay, & Sorrells, 2004).	<p>Medical and operational data</p> <ul style="list-style-type: none"> - Data collected from Transition System, Inc. (TSI) by Vanderbilt University Medical Center, Nashville, TN (Hendrich, Fay, & Sorrells, 2004).

Medical errors: Article analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Booker, J. M., & Roseman, C. (1995). A seasonal pattern of hospital medication errors in Alaska. <i>Psychiatry Research</i> , 57(3), 251-257.	Length of daylight	Average hours of darkness for each month (hr, data from public weather service)	Medication errors (omission, wrong time, wrong patient, wrong dose, wrong medication, error in transcription of physician's order, allergic medication, repeated medication, wrong route of administration, medication discontinued without physician authorization)	# of errors per month (error reporting form completed by the nurse committing the error and/or staff discovering the error)	Observational study, correlational analysis	The number of errors per month was positively associated with the average length of darkness two months earlier.	A 140-bed acute care hospital in Alaska	262 medication errors by nurses in a 5-year period
Buchanan, T. L., Barker, K. N., Gibson, J. T., Jiang, B. C., & Pearson, R. E. (1991). Illumination and errors in dispensing. <i>American Journal of Hospital Pharmacy</i> , 48(10), 2137-2145.	Illumination level	Three lighting levels by manipulating supplemental lighting fixtures (no supplemental fixtures - 45 ftc, two standard 4-foot fluorescent lighting fixtures with color filter - 102 ftc, and without color filter - 146 ftc); lighting level measured using photometer	Prescription-dispensing error rate	Number of prescriptions deviating in one or more ways from prescriber's written orders divided by the total number of prescriptions checked by each pharmacist and reviewed by the observer	Experiment, within-subject repeated measurements	Pharmacists made significant fewer errors in dispensing prescriptions when illumination level was high (146 ftc, 2.6%) than when the illumination level was relatively low (3.8%).	An outpatient pharmacy in a acute-care Army hospital	Five pharmacists
Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Berger, B. A., & Smith, L. A. (1999). Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. <i>American Journal of Health Systems Pharmacy</i> , 56(13), 1319-1325.	Interruption (the cessation of productive activity before current prescription-filling task was completed for any externally imposed, observable, or audible reason); Distraction (an external stimulus followed by the pharmacist continuing productive activity while responding to the stimulus in a manner that was observable)	# of interruptions and distractions per pharmacist per half hour (videotape review)	Prescription-dispensing error rate	# of dispensing errors per pharmacist per half hour; # of prescriptions involved errors divided by the total # of prescriptions (% filled prescriptions evaluated by researcher to detect deviations from physician's orders)	Observational study, correlational analysis	The number of interruptions and distractions per half hour was positively related to the number of dispensing errors per half hour. Sources of interruptions and distractions included unrelated traffics, prescription-processing questions, etc. It was recommended to eliminate traffic from other areas by relocating the ambulatory care pharmacy, providing visual barriers around the pharmacy, or rerouting traffic to an entrance that does not require passage through the ambulatory care pharmacy.	An ambulatory pharmacy at a general acute care hospital	14 pharmacists and 10 technicians
Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Smith, L. A., & Berger, B. A. (1996). Relationships between ambient sounds and the accuracy of pharmacists' prescription-filling performance. <i>Human Factors</i> , 38(4), 614-622.	Frequency of unpredictable, controllable / uncontrollable sounds; Sound level	# of unpredictable / controllable / uncontrollable sounds per minute (videotape review); Equivalent sound level (Leq) per each half hour (noise-logging dosimeter)	Prescription-dispensing error	Whether or not one or more dispensing errors exist in selected prescription set	Observational study, repeated measurements within subjects	Unpredictable and controllable sounds might have a arousal effect and reduced dispensing errors. The error rate increased to a point then decreased when equivalent sound levels increased.	A pharmacy at a general acute care hospital	31 matched pairs of prescription sets by 12 pharmacists
Flynn, E.A., Dorris, N.T, Holman, G.T., Garnahan, B.J., & Barker, K.N. (2002). Medication dispensing errors in community pharmacies: A nationwide study. <i>Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting</i> , 1448-1451.	Illumination level; Sound level; Physical configuration of drug stock storage shelves	Illumination level - above vs. below 94 ftc, measured by a Sper Scientific light meter; Sound level - recorded by a Sper Scientific sound meter; Physical configuration of drug stock storage shelves - separation and space in between items vs. tightly packed items on shelves	Prescription-dispensing error and near error (dispensing error refers to any deviation from the interpretable prescription including content errors [incorrect drug, form, quantity, and strength] and labeling errors [incorrect instructions and information]; near error refers to an error discovered and corrected by the pharmacy staff)	# of dispensing errors and near errors % of dispensing errors and near errors (un-disguised observation to detect deviations from physician's orders)	Observational study	The physical configuration of drug stock storage shelves with separation and space in between drug items was associated with fewer content errors than the configuration with minimal space between items. More errors were made in pharmacies with lower lighting levels. Higher lighting level and lower sound level was also associated with higher rate of detection of errors by pharmacy staff.	50 pharmacies in six states (chain, independent, and health-system pharmacies)	5784 prescriptions, 91 errors, 74 near errors
Hendrich, A. L., Fay, J., & Sorrells, A. K. (2004). Effects of acuity-adaptable rooms on flow of patients and delivery of care. <i>American Journal of Critical Care</i> , 13(1), 35-45.	Acuity-adaptable room	Renovation of nursing unit by combining two separate units (critical care unit and step-down unit) into one acuity adaptable unit	Patient transports between units; Annual index of medication errors	# of transports/month (medical records); # of errors/patient days (hospital's adverse event reporting system)	Comparison of data collected before/after the renovation of nursing unit	After moving to acuity-adaptable rooms, the number of patient transports between units decreased by 90%; the annual index of medication errors decreased by 70%.	Coronary care unit (critical and progressive care)	2 years of data before renovation and 3 years of data after

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
King, W. J., Paice, N., Rangrej, J., Forestell, G. J., & Swartz, R. (2003). The effect of computerized physician order entry on medication errors and adverse drug events in pediatric inpatients. <i>Pediatrics</i> , 112 (3 Pt 1), 506-509.	Computerized physician order entry (CPOE)	CPOE implemented in 2 nursing units, compared with other units using hand written orders	Rate of medication error (reported adverse event involving medication prescription, dispensing, administration, or monitoring); Rate of adverse drug event (ADE, a medication error resulting in an injury to the patient)	# of medication errors per 1000 patient days (adverse event reporting database); # of ADEs per 1000 patient days (physician review)	Quasi-experiment; Retrospective	The CPOE resulted into significant decrease in reported medication error rates (4.48 to 3.13 errors per 1000 patient days) in the intervention units. After the implementation of CPOE, the medication rate was 40% lower in the intervention units than in the control units. Only 18 ADEs were identified. No effects of CPOE on ADE rate were demonstrated.	A tertiary pediatric hospital	36103 discharges and 179183 patient days
Moorthy, K., Munz, Y., Dosis, A., Bann, S., & Darzi, A. (2003). The effect of stress-inducing conditions on the performance of a laparoscopic task. <i>Surgical Endoscopy</i> , 17(9), 1481-1484.	Noise	Operating room background noise (80 to 85 dB) vs. quiet condition	Surgical error (skill-based, knowledge-based)	Error score (summation of all the errors for the task)	Simulated experiment, within-subject repeated measurements	Significantly more errors were made under noisy condition than quiet condition. High noise levels in operating rooms may induce stress and increase surgical errors.	Operating rooms	13 surgeons with various level of experience
Pluyter, J. R., Buzink, S. N., Rutkowski, A. F., & Jakimowicz, J. J. (2010). Do absorption and realistic distraction influence performance of component task surgical procedure? <i>Surgical Endoscopy</i> , 24 (4), 902-907.	Distractions (popular songs combined with social conversation irrelevant to the surgical task and nonoptimal laparoscope navigation)	Distracting condition vs. non-distracting condition	Surgical performance of a clip and cut assessed (CCA) task	Task score, task completion, task errors, total time (measured by the simulator)	Simulated experiment, within-subject repeated measurements	Surgical task performance declined and errors increased significantly when a surgical task was performed under distracting condition.	Operating rooms	12 medical trainees
Poon, E. G., Cina, J. L., Churchill, W., Patel, N., Featherstone, E., Rothschild, J. M., . . . Gandhi, T.K. (2006). Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in the pharmacy. <i>Annals of Internal Medicine</i> , 145(6), 426-434.	A bar-code-assisted dispensing system; a dedicated medication repackaging center in pharmacy	Implementation of the bar-code-assisted dispensing system in 3 configurations, building of the dedicated medication repackaging center during the conversion process	Target dispensing errors (errors that the bar code technology was specifically designed to address, including wrong medication, wrong strength or dose, wrong formulation, expired medication); Target potential adverse drug event (errors that can harm patients)	Target dispensing error rate (% direct observation by a trained research pharmacist); Target adverse drug event rate (% errors reviewed by 2 board-certified internists)	Before-after study	After the implementation of the bar-code system, rates of dispensing error and potential adverse drug event decreased significantly. System configurations that required scanning of every dose had a bigger reduction in errors than configuration that did not require scanning of every dose.	Hospital pharmacy at a 735-bed hospital	About 370,000 medications
Ros, H. & de Vreeze-Wesselink, E. (2009). Reducing the number of dispensing errors by implementing a combination of a CPOE system and a bar-code-assisted dispensing system: The BAP concept. <i>EJHP Science</i> , 15 (4), 86-92.	Computerized physician order entry (CPOE); A bar code-assisted dispensing system using a bedside assortment picking (BAP) trolley	Implementation of the CPOE system and the bedside assortment picking (BAP) trolley	Dispensing error (unordered drug, extra dose, wrong dose, omission, wrong time, wrong route of administration, wrong form, wrong administration technique)	Dispensing error rate (# of errors divided by the sum of all doses ordered and the number of unordered doses given, expressed in %, direct observation)	Before-after study (baseline, implementation of CPOE, and then implementation of BAP trolley)	The dispensing error rate reduced by 47% after the implementation of the CPOE system (from 3.1% to 1.7%). BAP trolley resulted in an additional reduction in dispensing errors of 49% (from 1.7% to 0.84%). For BAP trolley, a well-protected cordless network is needed.	A 36-bed neurology ward in The Netherlands.	Over 12,500 doses
Westbrook, J. I., Woods, A., Rob, Marilyn, I., Dunsmuir, W. T. M., & Day, R. O. (2010). Association of interruptions with an increased risk and severity of medication administration errors. <i>Archives of Internal Medicine</i> , 170(8), 683-690.	Interruptions	# of interruptions during one medication administration	Medication administration procedural failure rate (% of medications with procedural failures); Medication administration error rate (% of medications with errors); Severity of error (five severity rating level and two categories - major and minor errors)	Percentage of administrations with procedural failures (% direct observation using a structured tool on a PDA); Percentage of administrations with medication errors (% comparison of observational data with medical charts); Error severity - major vs. minor errors (researcher determination based on 5-point severity assessment scale)	Observational	Overall, procedural failures occurred in 74.4% of medication administrations, and errors occurred in 25% of administrations. The rates of procedural failures and medication errors as well as error severity were positively related to the numbers of interruptions per medication administration.	Two Australian hospitals	4271 drug administrations for 720 patients

Medical errors: Matrix of relationships

		Outcome				
	Variable	Medication errors	Medication administration procedural	Adverse drug event	Surgical errors	Intra-hospital patient transfer
Environment feature	Distraction/Interruption					
	Noise					
	Light fixture					
	Illumination level					
	Daylight					
	Acuity-adaptable room					
	Bar-code-assisted dispensing system					
	Bedside assortment picking (BAP) trolley					
	Physical configuration of drug stock shelves					
	Computerized physician order entry (CPOE)					

Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

Patient falls: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environmental variable	Bed alarm, Medical vigilance system (bed sensors connected to nurse call system)	A passive sensor array, including bed exit sensors, embedded into a coverlet around the patient bed's mattress and connected to the nurse call system (Spetz et al., 2007)	Presence versus absence (Spetz et al., 2007)	Experimental manipulation - The medical vigilance system was installed on 42% of beds in a nursing unit. Outcomes of patients on these beds were compared with outcomes of patients on beds without the system (Spetz et al., 2007)
	Bedrail and other physical restraints	Physical restraints: mechanical or manual devices used to limit a patient's physical mobility (Capezuti et al., 1998). Bedrail: a rail or board running along the side of a patient bed; often used to prevent easy egress from the bed (Hanger et al., 1999).	- Nighttime bed rail use (Capezuti et al., 2002) - Physical restraints use (Capezuti et al., 1998) - Bed rail use (Hanger et al., 1999) - Bed rail use versus no use (Van Leeuwen et al., 2001)	Observation - Nighttime bed rail uses were classified into several levels--bilateral rail use, one-side rail use, no use of side rail (Capezuti et al., 2002). - Levels of physical restraints used in nursing homes were directly observed and classified into several levels: vest, wrist/ankle, belt, pelvic, geriatric/recliner chairs, wheelchairs with fixed tray tables (Capezuti et al., 1998) - In a fall-prevention program, bed rail use was reduced through policy change and education (Hanger et al., 1999) Incidence/accident reports - Bed rail use data were collected from patient incident form (Van Leeuwen et al., 2001)
	Falls - Multifaceted environmental intervention	Simultaneous modification of multiple aspects of the physical environment for the purpose of reducing patient falls and injuries (Becker et al., 2003; Brandis, 1999)..	Before versus after the implementation of a fall-prevention program including environmental modifications (Becker et al., 2003; Brandis, 1999)	Design manipulation - Environmental modification based on environmental hazard check and discussion with staff and administrators (lighting, chair and bed height, floor surfaces, room clutter, grab bars, walking aids) together with staff training, resident education, exercise and hip protectors) (Becker et al., 2003)
	Interior finish material	Material covering interior surfaces such as ceiling, floors, and walls (Calkins et al., 2011)	- Flooring type: carpet vs. vinyl (Donald et al., 2000; Healey, 1994), with vs. without carpet (Simpson et al., 2004); linoleum, VCT, ceramic tile (Calkins et al., 2011) - Flooring pattern: pattern size (no, small [less than 1"], medium [1'-6"], large pattern [>6"]) (Calkins et al., 2011)	Research Manipulation - Installation of a new carpet flooring (Donald et al., 2000). Incidence/accident reporting - Data about flooring types were gathered from the accident forms completed by nurses (Healey, 1994) Environmental inspection/audit - Existing flooring materials were examined through environmental inspection (Simpson et al., 2004)
	Noise	A sound that is loud, unpleasant, unexpected, or undesired (Free Dictionary)	- Alarms and overhead paging heard frequently, infrequently, never used (Calkins et al., 2011)	Environmental inspection/audit - Environmental inspection performed by hospital staff using the Falls Environment Evaluation Tool (FEET) (Calkins et al., 2011)

	Term	Definition	Metrics	Measurement method
	Nursing station layout	Spatial arrangement of nurse work stations in a nursing unit (Dutta, 2008; Gurascio-Howard & Malloch, 2007)	Types: decentralized versus centralized (Hendrich et al., 2004)	Design manipulation - Environmental changes implemented during a nursing unit renovation (Hendrich et al., 2004)
	Patient bathroom design	Architectural and interior design of bathrooms containing bath and toilet facilities for patients (Calkins et al., 2011).	Private versus shared or no bathroom; open versus closed door; 18" space on the opening side of bathroom door versus no space; bathroom located on footwall versus headwall; toilet on side wall versus across from entrance; two bars on both sides of toilet in bathroom, one bar, no bar (Calkins et al., 2011)	Environmental inspection/audit - Environmental inspection performed by hospital staff using the Falls Environment Evaluation Tool (FEET) (Calkins et al., 2011)
	Patient room layout	Spatial arrangement of architectural elements and equipment in patient rooms (Calkins et al., 2011).	- Designated family space versus no designated family space (Calkins et al., 2011)	Environmental inspection/audit - Environmental inspection performed by hospital staff using the Falls Environment Evaluation Tool (FEET) (Calkins et al., 2011)
	Subfloor	Rough floor serving as a base under a finished floor (Simpson et al., 2004)	Type: wood versus concrete (Simpson et al., 2004)	Environmental inspection/audit - Existing subfloor materials were identified through environmental inspection (Simpson et al., 2004)

	Term	Definition	Metrics	Measurement method
Fall related outcome	Fall-related injuries	<ul style="list-style-type: none"> Any graze, bruise, laceration, or fracture resulting from a fall; includes complaints resulting from a fall, even if a lesion is not visible (Healey, 1994). Serious injury: all fractures and other injuries resulting in medical attention and bed rest for at least 2 days. Minor injuries: do not meet the criteria for serious injury, e.g., bruises, abrasions, certain sprains, and other soft tissue injuries (Capezuti et al., 2002). Serious injuries: fractures; dislocation of joints; head injuries requiring neuro-observations; skin lacerations requiring skin grafts, suturing, or plastic surgical attention; and any hip pain preventing the patient from mobilizing, even if an X-ray shows no fracture. Minor injuries: small bruises, skin tears, and lacerations requiring cleansing and steristripping but no suturing (Hanger, Ball, & Wood, 1999). Minor injury: minor cuts, minor bleeding, skin abrasions, swelling, pain, minor contusions. Moderate injury: excessive bleeding, lacerations requiring sutures, temporary loss of consciousness, moderate head trauma. Severe injury: fractures, subdural hematomas, other major head trauma, cardiac arrest, and death (Hitcho et al., 2004). 	<p>Prevalence</p> <ul style="list-style-type: none"> Number of patients injured per 1,000 admissions (Brandis, 1999) Number of injuries per 1,000 patient days (Capezuti et al., 1998) <p>Severity</p> <ul style="list-style-type: none"> Percentage of falls resulting in injuries of different severity levels (Capezuti et al., 1998; Hanger et al., 1999; Schwendimann et al., 2006; Van Leeuwen et al., 2001) Number of hip fractures per 100 falls (Simpson et al., 2004) 	<p>Incidence/accident reporting system as described above</p> <ul style="list-style-type: none"> Nursing home incidence report (Capezuti et al., 2002) Routine data collection using incident forms (Hanger et al., 1999) Falls register of nursing home (Simpson et al., 2004) <p>Radiograph review</p> <ul style="list-style-type: none"> Radiograph review of hip fractures (Simpson et al., 2004)

	Term	Definition	Metrics	Measurement method
	<p>Falls, patient</p>	<p>There is no universally accepted definition of patient falls. The following definitions are used in literature and practice:</p> <ul style="list-style-type: none"> • An unplanned descent to the floor (or extension of the floor, e.g., trash can or other equipment) with or without injury to the patient, and occurring on an eligible reporting nursing unit. All types of falls are included, whether they result from physiological reasons (fainting) or environmental reasons (slippery floor). • Includes assisted falls which occur when a staff member attempts to minimize the impact of a patient's fall (NDNQI, 2005). • Unintentionally coming to rest on the ground, floor, or other lower level regardless of the cause (Becker et al., 2007). • A sudden, unanticipated change (downward) in body position with or without physical injury (Brandis, 1999). • An accidental collapse to the ground leading to the completion of an accident report form by nursing staff (Donald, Pitt, Armstrong, & Shuttleworth, 2000). • A sudden, unexpected descent from a standing, sitting, or horizontal position, including slipping from a chair to the floor, a patient found on the floor, and an assisted fall (Hitcho, 2004). 	<p>Prevalence</p> <ul style="list-style-type: none"> - Number of patient falls per 1,000 patient days (occupied bed days) (Calkins et al., 2011; Hendrich et al., 2004; Hitcho et al., 2004) - Number of patient falls per 1,000 resident year (nursing home) (Becker et al., 2003) - Number of patient falls per 100 patients (admissions) (Hanger et al., 1999; Van Leeuwen et al., 2001) - Number of patient falls per 1,000 admissions (Brandis, 1999) - Fall rate (number of falls per patient) (Spetz et al., 2007) <p>Severity</p> <ul style="list-style-type: none"> - Percentage of falls resulting in injuries (Capezuti, 2002; Healey, 1994; Hitcho et al., 2004) 	<p>Incidence/accident reports</p> <p>Most patient falls data come from incidence/accident report forms completed by nurses. Therefore, the quality of data relies on the work of individual nurses. An incident report form of patient falls usually includes patient information (e.g., demographics, diagnosis, fall risk assessment), details of fall incident, circumstantial/environmental factors contributing to the fall (e.g., staff ratio, floor condition), and the results of the fall (e.g., injury levels).</p> <ul style="list-style-type: none"> - Falls calendar sheets completed by nurses daily (Becker et al., 2003) - Nursing home incidence report (Capezuti, 2002; Capezuti et al., 1998) - Accident forms reported by nurses (Healey, 1994) - Hospital's adverse event reporting system (Hendrich et al., 2004) <p>Medical records</p> <ul style="list-style-type: none"> - Medical records were examined to calculate fall rate (Spetz et al., 2007)

Patient Falls: Article Analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Becker, C., Kron, M., Lindemann, U., Sturm, E., Eichner, B., Walter-Jung, B., & Nikolaus, T. (2003). Effectiveness of a multifaceted intervention on falls in nursing home residents. <i>Journal of the American Geriatrics Society, 51</i> (3), 306-313.	Environmental modification based on environmental hazard check and discussion with staff and administrators (lighting, chair and bed height, floor surfaces, room clutter, grab bars, walking aids) together with staff training, resident education, exercise and hip protectors)	Before vs. after the implementation of a fall prevention program	Incidence density rates of falls, fallers, frequent fallers (>2), hip fractures, and non-hip fractures (number of incidence per 1000 resident years). Quarterly data.	Falls calendar sheets completed by nurses daily	Prospective, cluster-randomized controlled trial, 3 nursing homes as intervention group and 3 as control group	Significant lower incidence density rate of falls, fallers, and frequent fallers in the intervention group. Due to low rate of fractures in both groups, larger sample size would be needed to detect an interventional effect.	6 nursing homes in Germany	Nursing home residents (n=981)
Brandis, S. (1999). A collaborative occupational therapy and nursing approach to falls prevention in hospital inpatients. <i>Journal of Quality in Clinical Practice, 19</i> (4), 215-220.	Environmental modifications on design faults in bathrooms (slippery floors, inappropriate door openings, poor placement of rails and accessories, incorrect toilet and furniture heights) together with other changes (high-risk patient flagging system, education) were included in the patient fall prevention program	Before vs. after the implementation of a fall prevention program	Fall incidence rate (number of falls per 1000 occupied bed days, number of patient falling per 1000 admissions, falls per weighted separations taking into account patient acuity) Fall-related injury rate (Percentage of patients falls resulting in injury [bruise, abrasion, laceration, fracture, etc.], number of patients injured per 1000 admissions)	Incidence forms database Injury rates are reliable as these are more likely to be reported.	Before-after the intervention of a patient falls prevention program	A comparison between patient fall data showed a decrease in falls and fall-related injuries after the implementation of the patient falls prevention program including environmental modifications	An Australian hospital	One year of data before and one year of data after intervention
Calkins, M.P., Biddle, S., & Biesan, O. (2011). <i>Contribution of the designed environment to fall risk in hospitals</i> . Concord, CA: Center for Health Design.	Bathroom design Patient room layout Flooring materials Noise Other environmental factors	Environmental inspection/audit using the Falls Environment Evaluation Tool (FEET) - Bathroom: private vs. shared or no bathroom; open vs. close door; 18" space on the opening side of bathroom door vs. no space; bathroom on footwall vs. headwall; toilet on side wall vs. across from entrance; two bars on both sides of toilet in bathroom, one bar, no bar; Patient room: designated family space vs. no designated family space Flooring: pattern size (no, small [less than 1"], medium [1'-6"], large pattern [>6"]); linoleum, VCT, ceramic tile Noise: alarms and overhead paging heard frequently, infrequently, never used	Patient fall rate: number of falls per 1000 patient days	Data provided by participating facilities, collected from medical records - total number of patient days, location of patient falls	Observational study	The following environmental factors were found to be associated with lower rates of patient falls: private bathroom (as opposed to shared or no bathroom), bathroom door that could remain in an open position, 18" space available at the opening side of the bathroom door, bathroom on footwalls (vs. headwalls), toilet on the side wall of bathroom (vs. toilet across from the entrance), two grab bars on both sides of the toilet (vs. one bar, two bars on wall), designated family space in patient room. Factors associated with more falls included: medium size flooring pattern (vs. no, small, or large pattern), linoleum flooring (vs. VCT, ceramic tile), and frequently heard alarms and overhead paging.	27 patient units in 12 hospitals	995 falls, 670 patient rooms
Capezuti, E., Maislin, G., Strumpf, N., & Evans, L. K. (2002). Side rail use and bed-related fall outcomes among nursing home residents. <i>Journal of the American Geriatrics Society, 50</i> (1), 90-96.	Nighttime side rail use	Levels of side rail use, including bilateral rail use, one-side rail use, no use of side rail (direct observation)	Presence or absence of bed-related falls, falls resulting in serious injuries (fractures, dislocated joint, subdural hematoma, laceration requiring sutures), and recurrent falls	Nursing home incidence report	Longitudinal study, repeated measurement; Comparisons between patients with different levels of bed rail use	There was an increase in bilateral side rail use over a 1-year period observation period probably due to declines in residents' physical and cognitive function. Bilateral bed rail use was not associated with reduced fall risk.	Three nonprofit nursing homes	463 residents in 3 nursing homes

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Capezuti, E., Strumpf, N. E., Evans, L. K., Grisso, J. A., & Maislin, G. (1998). The relationship between physical restraint removal and falls and injuries among nursing home residents. <i>Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 53</i> (1), M47-52.	Physical restraints	Three levels of physical restraints use in nursing homes including vest, wrist/ankle, belt, pelvic, geriatric/recliner chairs, wheelchairs with fixed tray tables (direct observation)	Individual level: presence or absence of any fall, fall with minor or serious injury; Institutional level: fall rate (# of falls per 1000 patient days), fall-related injury rate (# of injuries per 1000 patient days; major injury: all fractures and other injuries resulting in medical attention and bed rest for at least 2 days; minor injury: bruises, abrasions, certain sprains, and other soft tissue injuries) Crude and adjusted incidence density ratio (ratios calculated by dividing one nursing home's incidence rate by the rate of the control nursing home)	Nursing home incident report	Comparison of residents with restraints removed and those who remained to be restrained; Comparison of nursing homes with different level of restraints use	The removal of restraints was associated with lower fall rates and injury rates.	Three nursing homes in the Philadelphia area	126 residents (restraint users at baseline); 633 residents (including non restraint users)
Donald, I. P., Pitt, K., Armstrong, E., & Shuttleworth, H. (2000). Preventing falls on an elderly care rehabilitation ward. <i>Clinical Rehabilitation, 14</i> (2), 178-185.	Flooring type; Type of physiotherapy	Two flooring types - carpet and vinyl (experimental manipulation: Installation of new carpet and use of physiotherapy)	Number of patient fallers, number of falls	Accident report form by nursing staff	Experiment design, randomization but significant dropouts	Vinyl flooring (compared to carpeting) and physiotherapy with additional leg strengthening exercises were associated with lower risk of falls but the differences were not statistically significant due to small sample size.	Elderly care rehabilitation ward in a community hospital in UK	54 patients
Hanger, H. C., Ball, M. C., & Wood, L. A. (1999). An analysis of falls in the hospital: Can we do without bedrails? <i>Journal of the American Geriatrics Society, 47</i> (5), 529-531.	Reduction of bed rail usage by policy change and education program	Implementation of fall prevention program	Falls per 100 admissions, Falls per 10,000 bed days Number of injuries (serious, minor), staff injuries	Routine data collection using incident forms	Before-after the intervention (restriction of bedrail use)	After the reduction of bedrail use, fall rate did not change but the number of serious injuries was significantly reduced.	Five wards for older people in a New Zealand hospital	1968 hospital ward admissions in 12-month period (987 before and 981 after)
Healey, F. (1994). Does flooring type affect risk of injury in older in-patients? <i>Nursing Times, 90</i> (27),40-41.	Flooring type	Two flooring types - carpet vs. vinyl (accident form reported by nurses)	Proportion of falls resulting in injuries	Accident form reported by nurses	Retrospective observational study	Vinyl flooring was associated with higher risk of injury. Four (17%) out of 27 patients who fell on carpet received injuries; 91 (46%) of 186 patients who fell on vinyl flooring received injuries.	A care of the elderly unit in UK	213 accident forms randomly selected
Hendrich, A. L., Fay, J., & Sorrells, A. K. (2004). Effects of acuity-adaptable rooms on flow of patients and delivery of care. <i>American Journal of Critical Care, 13</i> (1), 35-45.	Acuity-adaptable room with decentralized nurse stations and supplies	Renovation of nursing unit	Patient fall index: number of falls per 1000 patient days). Yearly data.	Hospital's adverse event reporting system	Before-after the renovation of nursing unit	The annual patient fall index decreased from 4 or more falls per 1000 patient days to 2 falls per 1000 patient days.	Coronary care unit (critical and progressive care)	2 years of data before renovation and 3 years of data after
Hitcho, E., Krauss, M., Birge, S., Dunagan, W., Fischer, I., Johnson, S., . . . Fraser, V.J. (2004). Characteristics and circumstances of falls in a hospital setting. <i>Journal of General Internal Medicine, 19</i> (7), 732-739.	Environmental circumstances and environmental interventions used by nurses	Adverse event report system; Observation; Interview	Fall rate (number of falls per 1000 patient days) Number of falls resulting in different types of injuries	Adverse event report system	Prospective descriptive study of falls and environmental and other factors related to falls	Most falls were unassisted, elimination-related, and occurred in patient rooms at night. The most common used fall interventions were video surveillance or placement patients close to the nurse station and restraints. Environmental contributors to falls included wet floor and environmental obstacles (furniture, device, equipment).	A 1300-bed urban academic hospital	200 falls occurred in 34 units in 7 services
Schwendimann, R., Buhler, H., De Geest, S., & Milisen, K. (2006). Falls and consequent injuries in hospitalized patients: Effects of an interdisciplinary falls prevention program. <i>BMC Health Services Research, 6</i> , 69.	Interdisciplinary fall prevention program (including patient screening, environmental modifications, etc.)	Implementation of fall prevention program	Patient fall rate: number of falls per 1000 patient days Severity of fall-related injuries (annual percentage of falls resulting in no injuries, minor injuries, and major injuries)	Standardized fall incident report form	Before and after study	A slight but nonsignificant decrease in patient falls was observed after the implementation of falls prevention program. No significant reduction in the severity of fall-related injuries.	A 300-bed urban public hospital	34972 hospitalized patients from 1999 to 2003

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Simpson, A. H., Lamb, S., Roberts, P. J., Gardner, T. N., & Evans, J. G. (2004). Does the type of flooring affect the risk of hip fracture? <i>Age and Ageing</i> , 33 (3), 242-246.	Floor types (underfloor structure and floor covering): wood sub-floor w/ carpet wood sub-floor w/o carpet concrete sub-floor w/ carpet concrete sub-floor w/o carpet	Inspection and classification of floors	Number of falls, number of hip fractures per 100 falls (falls register, clinical records, radiographs)	Falls register of nursing home, radiograph review of fractures	Observational study	Wooden carpeted floors had lowest number of fractures per 100 falls. Compared to wooden sub-floor, concrete sub-floor was related to a higher risk of hip fracture in a fall. Carpeting was not associated with significantly lower risk of hip fracture. More falls occurred in carpeted floors. But this might be related to the large amount of time residents spent in carpeted rooms.	34 residential care homes in UK	733 rooms, 6641 falls and 222 fractures
Spetz, J., Jacobs, J., & Hatler, C. (2007). Cost effectiveness of a medical vigilance system to reduce patient falls. <i>Nursing Economic\$, 25 (6)</i> , 333-338, 352.	A medical vigilance system (bed sensors connected to nurse call system)	Experimental manipulation	Fall rate (number of falls divided by number of patients) Cost per patient Length of stay	Medical records	Quasi-experiment	The fall rate was 0.0194 for patients in beds with the vigilance system and 0.0323 for patients in beds without this system. The estimated incremental cost of the vigilance system was around 6,000 per avoided fall.	A 24-bed post-neurosurgery unit	567 patients
Van Leeuwen, M., Bennett, L., West, S., Wiles, V., & Grasso, J. (2001). Patient falls from bed and the role of bedrails in the acute care setting. <i>Australian Journal of Advanced Nursing</i> , 19 (2), 8-13.	Bedrail use (used vs. not used)	Patient incident form	Fall rate (number of falls per 1000 patient admissions) Injury severity	Patient incident form, nurse notes	Retrospective observational study	For all age-gender groups, the rate of falls from bed when bedrails were used was higher than or equal to when bedrails were not used. No difference was found in injury severity.	An urban acute care hospital	419 patient falls from 1993 to 2000

Patient falls: Matrix of relationships

		Outcome	
	Variable	Patient falls	Fall-related injuries
Environmental feature	Nursing station layout		
	Interior finish material		
	Subfloor		
	Bedrail and other physical restraints		
	Medical vigilance system (bed sensors connected to nurse call system)		
	Multifaceted environmental intervention		
	Patient bathroom design		
	Patient room layout		
	Noise		

Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

Patient Satisfaction: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environmental variable	Acoustic ceiling tile	Ceiling tiles that absorb sound reflected off hard surfaces and can be used in a grid or direct-glued to a solid ceiling deck. Typically porous, these products accept and trap sound/vibration and allow it to dissipate before leaving the products (ASI Pro Audio Acoustics, 2010).	- Yes/no, before/after - Noise Reduction Coefficient (NRC) - A measure for rating the overall sound-absorption performance of a material when used in an enclosed architectural space such as an office where sound is being reflected at many angles of incidence. Specifically, it is the 4 frequency averaged absorption coefficients @ 250, 500, 1000 and 2000 Hz, rounded to the nearest 0.05. A material with NRC < 0.50 is a poor absorber, and NRC > .80 is a very good absorber (Armstrong, 2010).	Design manipulation - First, sound-reflecting ceiling tiles (13 mm solid painted plaster board tiles) were installed. Four weeks later, the ceiling tiles were replaced with sound absorbing ceiling tiles (40 mm Ecophon high density resin bonded glass wool with a painted surface) of nearly identical appearance (Hagerman, et al., 2005)
	Acuity-adaptable room	Rooms designed with sufficient space and provision for equipment, medical gases, and power to accommodate any level of patient acuity (Evans, Pati, & Harvey, 2008).	- Yes/no, before/after (Hendrich, Fay, & Sorrells, 2004)	Design manipulation - The coronary critical care unit and medical step-down unit were redesigned and combined into one acuity-adaptable unit (Hendrich, Fay, & Sorrells, 2004).
	Amenities	Features of health services that do not relate directly to clinical effectiveness but may enhance the client's satisfaction and willingness to return (Brown, Franco, Rafeh, & Hatzell, 1998)	- Level of amenities: high level of amenities (windows, maple furniture, sofa chairs, soundproofing walls, private bathrooms) vs. low amenities (old, 'high-tech, low-touch', dark, small bathrooms) (Janssen, Klein, Harris, Soolsma, & Seymour, 2000), amenities such as décor and entertainment facilities appropriate for children (Judkins, 2003)	Design manipulation - New single-room maternity care unit with more amenities versus old rooms (Janssen et al., 2000); - New ED dedicated to pediatric patients with décor and entertainment appropriate for children (Judkins, 2003)

	Term	Definition	Metrics	Measurement method
	Attractiveness, physical environment	Aesthetic appeal of the physical environment, including the surrounding external environment, the architectural design, facility upkeep and cleanliness, and other physical elements (Becker & Douglass, 2008)	<ul style="list-style-type: none"> - Physical environment attractiveness score (summation of ranks) (Becker & Douglass, 2008) - Appealing room versus typical room (Swan et al., 2003) 	<p>Subjective rating</p> <ul style="list-style-type: none"> - Four photos of each of six facilities were presented to six university graduate students in non-design majors. The students were asked to rank the environments from most attractive (6) to least attractive (1). The ratings from all students regarding one facility were summed to create an environmental attractiveness score with a higher score reflecting a more attractive environment (Becker & Douglass, 2008). <p>Design manipulation</p> <ul style="list-style-type: none"> - Appealing, hotel-like rooms featured wood furniture, decorator art, carpeted floors, crown molding, and ceramic tile baths (Swan et al., 2003)
	Noise	A sound that is loud, unpleasant, unexpected, or undesired (Free Dictionary)	<ul style="list-style-type: none"> - Equivalent sound pressure level (LAeq) (constant noise level that would result in the same total sound energy being produced over a given period) (Hagerman et al., 2005) - Reverberation time (time needed for the sound pressure level to decrease by 60 dB) measured in central areas and two patient rooms in the unit (Hagerman et al., 2005) 	<p>Acoustic measurement</p> <ul style="list-style-type: none"> - Acoustic measurement by a third-party company (Hagerman et al., 2005)
	Patient room occupancy	The number of patients per patient room—one (single room, private room), two (double room), four (multi-bed open bays) (Nguyen Thi, Briancon, Empereur, & Guillemin, 2002; Soufi et al., 2010).	Single room versus 2 or 3 patients per room (Nguyen Thi, Briancon, Empereur, & Guillemin, 2002); Double room versus six-bed room (Soufi et al., 2010)	<p>Existing data from medical or administrative records</p> <ul style="list-style-type: none"> - Health characteristics including admission room (double/common) were collected at admission (Soufi et al., 2010)
	Positive distractions	A set of environmental features or conditions that have been found by research to effectively reduce stress. These features or conditions include nature and certain types of music, companion animals, laughter or comedy, and certain types of art (Ulrich, 1991).	- Yes/no, before/after (Diette et al., 2003; Lee et al., 2004)	<p>Design and experimental manipulation</p> <ul style="list-style-type: none"> - 42x52 photographic quality mural of a mountain stream in a spring meadow, mounted from the ceiling at bedside so patients could view it supine, nature sounds played with a portable tape recorder (Diette et al., 2003) - Classical music and home-made movie (mainly scenic views) provided by an Eyetrek system (Olympus, Japan) (Lee et al., 2004)

	Term	Definition	Metrics	Measurement method
Outcome	Anxiety	State anxiety: reflects a transitory emotional state or condition of the human organism that is characterized by subjective, consciously perceived feelings of tension and apprehension and heightened autonomic nervous system activity. Trait anxiety: denotes relatively stable individual differences in anxiety proneness; refers to a general tendency to respond with anxiety to perceived threats in the environment (Spielberger, Gorsuch, and Lushene, 1970)	- The Spielberger State-Trait Anxiety Inventory (S-STAI) score - the summation or average of items (Diette et al., 2003; Rice, Ingram, & Mizan, 2008; Routhieaux & Tansik, 1997)	Questionnaire survey - Six-item short version of the state anxiety measure (calm, tense, upset, relaxed, content, worried) from the Spielberger State-Trait Anxiety Inventory was included in a questionnaire completed by a patient twice - while waiting to begin the procedure and the second day following the procedure (Diette et al., 2003).
	Patient loyalty	Patient's long-term commitment to a preferred healthcare service provider; a manifestation of attitudes and actual purchasing behaviors (Hsu, Hsu, & Chiu, 2009)	Willingness to recommend or return, ratings of Likert scale (Nguyen Thi et al., 2002; Swan et al., 2003)	Questionnaire survey - Two questions in Patient Judgments of Hospital Quality questionnaire (PJHQ) about intention of recommending the hospital or returning (Nguyen Thi et al., 2002)
	Satisfaction, patient	Degree to which an individual regards a provider's health care service, product, or the manner in which the service or product is delivered as useful, effective, or beneficial (NLM MeSH).	- Scores of Likert type scales or subscales calculated (summation or average of items in the each scale/subscale) (e.g. Groff et al., 2008; Janssen et al., 2000;) - % of "excellent" responses (Becker & Douglass, 2008) - % of patients who are dissatisfied (Hendrich, Fay & Sorrells, 2004) - Score of a single question of patient satisfaction (Leather et al., 2003; Lee et al., 2004)	Questionnaire survey - Questionnaires (8 subscales - e.g., information and support, being with family and friends, privacy needs, physical environment) were distributed on the day of delivery and completed after delivery and before discharge (Janssen et al., 2000). A questionnaire including 16 items from a patient judgment system (PJS) developed by the Hospital Corporation of America was distributed to patients before and after the movement to a new unit. Patients completed the questionnaires independently or with help from nurses. The completed questionnaires were collected by nurses (Kline et al., 2007) - Patients were offered a questionnaire survey when completing their clinic visits and asked to fill out a questionnaire on-site or mail in the completed questionnaire from home. The quality of care index was the average percentage of "excellent" responses to 4 questions related to care, services, and interactions with staff and doctors (Becker & Douglass, 2008) - Patient Expectation Project standardized tool (Arbor Associates, Inc., Potoskey, MI) measuring how closely patients' experiences meet their expectations (Hendrich, Fay & Sorrells, 2004) - Satisfaction score on a 10 cm visual analog scale (0 =not satisfied, 10 = very satisfied) (Lee et al., 2004)

Patient Satisfaction: Article Analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Becker, F., & Douglass, S. (2008). The ecology of the patient visit: physical attractiveness, waiting times, and perceived quality of care. <i>Journal of Ambulatory Care Management, 31</i> (2), 128-141.	Physical environment attractiveness	Physical environment attractiveness score (summation of ranks based on subjective ratings)	Patient perceived quality of care; Patient perceived staff interactions; Patient anxiety; Patient recommendation of facility; Patient perceived waiting time.	- Quality-of-care index: % of "excellent" responses to a question (patient questionnaire survey, 4 questions: The care I received here today was...; The service I received here today was...; Overall, my interactions with staff were...; Overall, my interactions with doctors were...); - Staff-interaction index; - Patient anxiety ("environment helped to ease my anxieties"); % of responses in the "top box" - Perceived waiting time (percentage of respondents in categories from 0-5 minutes to more than 30 minutes)	Correlational study; cross sectional	Higher ratings of environmental attractiveness were associated with more favorable perceptions of the quality of care, a higher percentage of anxiety reduction, higher ratings of staff interactions.	Six outpatient facilities in New York	Six graduate students, 205 outpatients
Chang, S-C., & Chen, C-H. (2005). Effects of music therapy on women's physiological measures, anxiety and satisfaction during Cesarean delivery. <i>Research in Nursing and Health, 28</i> (6), 453-461.	Music	Three types of relaxing, anxiety-reducing music chosen by participants: Western classical, new age, or Chinese religious music.	Patient anxiety Patient physiological indexes Birth satisfaction	- The visual analogue scale for anxiety (VASA), consisting of a 10 cm horizontal line with the descriptors no anxiety at the left and worst possible anxiety at the right. The participants were asked to indicate how anxious they were feeling "right now" by marking the appropriate place on the line. - Pulse hemoglobin oxygen saturation (SpO2, NONIN MODEL 9500 pulse oximeter), temperature of the finger (Biofeedback System DT-002 thermometer), respiration rate, pulse rate, systolic blood pressure, and diastolic blood pressure (Hewlett Packard 78352A). - Satisfaction of cesarean delivery scale (SCDS), seven items (including the woman's perceived health status, the perceived health status of the baby, the maintenance of physical function, the maintenance of physical comfort, seeking safe passage for herself, ego orientation, and birth atmosphere), 5-point Likert scale, adequate content validity (CVI = .94) and internal consistency (Cronach's alpha = .86)	Experiment	Women in the music listening group had lower anxiety than their peers in the control group during the end of maternal contact with the neonate in the intraoperation period and after completion of the skin sutures. They also reported greater satisfaction with the cesarean experience.	A academic hospital in Taiwan	64 women having a cesarean delivery

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Diette, G. B., Lechtzin, N., Haponik, E., Devrotes, A., & Rubin, H. R. (2003). Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: A complementary approach to routine analgesia. <i>Chest</i> , 123 (3), 941-948.	Positive distractions (nature scene and sound)	Intervention (42x52 photographic quality mural of a mountain stream in a spring meadow, mounted from the ceiling at bedside so patients could view it in supine position, nature sounds played with a portable tape recorder) vs. control (no nature scene mural and nature sound) cared in the same unit	State anxiety; Pain control; Ability to breathe; Satisfaction with care	- State anxiety - six-item short version of the state of anxiety measure from the Spielberger State-Trait Anxiety Inventory (S-STAI), calm, tense, upset, relaxed, content, worried, 4-point scale, not at all to very much so; the summation of items were normalized to scores from 20 (low) to 80 (high); - Pain control - one question about how well pain was controlled during the procedure (poor to excellent), percentage of responses in 'very good' or 'excellent'; - Ability to breathe, percentage of responses in 'very good' or 'excellent'; - Satisfaction with care (willing to return, privacy, safety, overall rating), percentage of responses in 'definitely', or 'very good' or 'excellent'	Field experiment, patients on one certain day were assigned to intervention or control group	Patients who had access to nature murals and nature sounds at bedside reported better pain control after adjustment for demographics. Among indicators of patient satisfaction, privacy and the overall facility were more favorably rated by patients in the intervention group; however the differences were not significant.	Endoscopy suite in a teaching hospital in Baltimore, MD	80 patients undergoing flexible bronchoscopy (41 intervention, 39 control)
Groff, S. L., Carlson, L. E., Tsang, K., & Potter, B. J. (2008). Cancer patients' satisfaction with care in traditional and innovative ambulatory oncology clinics. <i>Journal of Nursing Care Quality</i> , 23 (3), 251-257.	Outpatient clinic environment (multiple factors)	New oncology clinic (separated waiting sub-areas, soothing music, viewing of nature scenes, warm wall colors, lighting, pagers to inform patients of their appointments, dedicated patient parking) vs. old clinic (one big room, "hospital like" colors, only one small TV, parking that was difficult to access)	Patient satisfaction	- Patient Satisfaction Questionnaire (PSQ-III), 43 items in 6 subscales (general satisfaction, technical quality, interpersonal care, communication, time spent with provider, access/availability/ convenience), each subscale was calculated on a 0-100 scale; - Additional 17 items in 6 domains (from other instruments and self-constructed): physical environment, wait times, continuity of care, confidentiality of information, trust in providers, interpersonal care)	Pre-post comparison with control group (three patient groups - one moved to a new clinic, the others stayed in the same clinic)	There were no significant differences between the three patient groups on the subscales before the move. After the lung cancer patients moved to the new clinic, patients in this group were more satisfied with the physical environment and wait time than those patients remained on the old clinic.	A academic cancer center in Canada	698 oncology outpatient with lung, head and neck, or gynecological tumor
Hagerman, I., Rasmanis, G., Blomkvist, V., Ulrich, R., Eriksen, C. A., & Theorell, T. (2005). Influence of intensive coronary care acoustics on the quality of care and physiological state of patients. <i>International Journal of Cardiology</i> , 98 (2), 267-270.	Ceiling tile type; Acoustics (noise level, reverberation time)	Ceiling tile - sound-reflecting (13-mm solid painted plaster board tiles) vs. sound absorbing (40-mm Ecophon high density resin bonded glass wool with a painted surface, class A); Equivalent sound pressure level (L _{Aeq}) and reverberation time measured in central areas and two patient rooms in the unit	Patient perceived quality of care; Blood pressure data (pulse amplitude, heart rate, heart rate variability); Short time prognosis	- Visual analogue scales with scores from 0 to 10, six questions (overall quality of care, staff attitude, waking due to sounds, intelligibility of what staff say, sounds from the corridor, disturbances due to sounds); - Blood pressure, pulse amplitude (mm Hg), heart rate (beats/min), heart rate variability (ms) assessed in supine position by an automatic device (MIDA, Ortivus Medical, Sweden); - Rehospitalization and mortality within 1 and 3 months (percentage)	Before-after, repeated measurements	Patients' satisfaction with overall quality of care and their ratings of staff attitude was better in the sound absorbing ceiling tile condition. Patients reported that they overheard sounds from the corridor and wake up due to sounds more often in the sound reflecting ceiling tile condition. Higher rate of Rehospitalization was found in the groups of patients hospitalized during the period of sound reflecting ceiling tiles. In patients with acute myocardial infarction and unstable angina pectoris, lower values in pulse amplitude were found in the sound absorbing ceiling tile condition.	A intensive coronary heart unit in Sweden	94 patients

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Harris, D., Shepley, M. M., & White, R. (2006). <i>The impact of single family NICU rooms</i> . San Francisco, CA: Coalition for Health Environments Research	Patient room occupancy type	Single family room vs. open bay (two types in a NICU)	Parent satisfaction with the physical environment; Parent perception of the physical environment; Parent perceived stress	- Degree of satisfaction with the physical environment, 10 questions, 5-point scale, average score (overall physical environment, windows views, natural light, light level, noise level, atmosphere and decor, waiting and resting space, corridors and signage for wayfinding, place for food and nourishment) - Level of agreement with statement regarding the physical environment, 12 questions, 5-point scale, average score (e.g. quiet, private space for family to be alone) - Three subscales of Parental Stress Scale: Neonatal Intensive Care Unit - sights and sounds, parent role, staff behaviors and communication, 5-point scale, average score	Comparison between two types of beds in one NICU	Descriptive analysis showed that parents in single rooms seemed to be more satisfied with the physical environment. The biggest difference was with regard to window views and place to sleep near infants. Parents felt less stressful and depressing in single rooms than in open bays.	A level III NICU in US	21 respondents (16 parents in single rooms, 5 in open bays)
Harris, P. B. (2002). A place to heal: Environmental sources of satisfaction among hospital patients. <i>Journal of Applied Social Psychology, 32</i> (6), 1276-99	Patient satisfaction with physical environment	Modified Patient Perceptions of Quality Interview-Inpatient Form (PPQ-I) facilities scale (3 items, overall quality of room, environment outside of room, cleanliness of room)	Patient overall satisfaction Patient satisfaction with individual aspects of patient care (e.g. nursing, physician, clinical quality)	- PPQ-I, 15 items, overall satisfaction (1 item), six aspects of service quality (10 items, nursing care, physician care, admitting, discharge, food, housekeeping), clinical quality (4 items). - Modified PPQ-I. 4 subscales, nursing scale and physician scale (3 items each, information provided, caring and concern, professional skill), clinical scale (4 items, condition improved, staff tried to improve condition, tests and treatment appropriate, staff tried to alleviate pain), facilities scale (3 items, overall quality of room, environment outside of room,	Correlational study	Patient satisfaction with the physical environment was a significant predictor of patient overall satisfaction with healthcare, although not as strong a predictor as nursing care and clinical quality. Sources of satisfaction with the environment includes equipment (TV), furniture (bed), finishes (wall finishes), color and decor (artwork), plan and layout of the room (accessibility).	Six hospitals in one system: 2 small, 2 mid-sized, 2 large	380 inpatients
Hendrich, A. L., Fay, J., & Sorrells, A. K. (2004). Effects of acuity-adaptable rooms on flow of patients and delivery of care. <i>American Journal of Critical Care, 13</i> (1), 35-45.	Acuity-adaptable room	Renovation of nursing unit by combining two separate units (critical care unit and step-down unit) into one acuity adaptable unit	Patient dissatisfaction	- Patient Expectation Project standardized tool (Arbor Associates, Inc., Potoskey, MI) measuring how closely patients' experiences meet their expectations and key factors that predict patient overall willingness to choose the hospital again or to recommend it to family and friends, measured by the percentage of patients who are dissatisfied (e.g. not made to feel less nervous or withdrawn, not treated with respect and dignity, nurses not friendly and caring)	Before-after study, comparison of data collected before/after the renovation of nursing unit	Patients' level of dissatisfaction decreased significantly in various predictive indicators. Patient's overall dissatisfaction rate decreased from 6% to 3% in the three years after the move.	Coronary care unit (critical and progressive care)	2 years of data before renovation and 3 years of data after

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Janssen, P. A., Klein, M. C., Harris, S. J., Soolsma, J., & Seymour, L. C. (2000). Single room maternity care and client satisfaction. <i>Birth, 27</i> (4), 235-243.	Maternity room design (function, size, amenities)	LDRP rooms (new spacious single rooms, windows, maple furniture, sofa chairs, soundproofing walls, and private bathrooms) vs. separate delivery and postpartum rooms (old, combination of double-occupancy and single rooms, 'high tech, low touch', dark, small bathrooms)	Patient satisfaction	- Satisfaction in 8 areas: information and support, being with family and friends, privacy needs, physical environment, nursing care, teaching, feeding baby, discharge planning; a scale of 1-5, 1 very dissatisfied, 5 very satisfied); surveys distributed on the day of delivery and completed after delivery and before discharge, average scores.	Pre-post & concurrent comparison; one intervention group, two comparison group	Patients in single room maternity care rooms were more satisfied in all the eight areas measured by the questionnaire survey (including the following aspects of the physical environment: spacious and adequate, able to find supplies, support person was comfortable, lighting, privacy).	Maternity care unit in an obstetric hospital in Canada	205 patients in single room maternity care unit, 221 similar patients in traditional rooms before the single room maternity care unit was opened, and 104 patients in traditional rooms when the single room maternity care unit was in use.
Judkins S. (2003). Paediatric emergency department design: Does it affect staff, patient and community satisfaction? <i>Emergency Medicine, 15</i> (1), 63-67.	ED design	ED waiting and treatment areas dedicated to pediatrics, physical separation between pediatrics and adult ED, décor and entertainment facilities appropriate for children	Patient/family, staff, physician satisfaction	- Questionnaire (individualized, 6 questions for patient/family), 5 point rating from 1 poor to 5 excellent, number and percentage of responses in each category	Before-after comparison (the month before and 6 moth after the move)	Patients' families in the new dedicated pediatric ED had more positive perceptions of the physical environment and were more satisfied with the overall management of the children.	A major metropolitan teaching hospital in Australia	93 patients' families
Kline, T. J., Baylis, B. W., Chatur, F., Morrison, S. A., White, D. E., Flin, R. H., & Ghali, W.A. (2007). Patient satisfaction: Evaluating the success of hospital ward redesign. <i>Journal of Healthcare Quality, 29</i> (3), 44-49.	Nursing unit design	New ward (predominance of private rooms, spacious areas for families and visitors, unique infection control design features, abundance of computer terminals for staff, wireless communication) vs. traditional ward lacking the above features	Patient satisfaction	- 16 items from a patient judgment system (PJS) developed by the Hospital Corporation of America (95 items in the original survey) - patients' immediate physical environment (4 items), general hospital environment (5 items), staff-patient interactions (3 items), overall satisfaction (4 items). 5-point and 4-point scales, composite scores were the sum of the item scores	Before-after comparison, correlational analysis	The new ward was rated significantly higher in all items of immediate physical environment and overall satisfaction, and one item in general hospital quality (medical facilities). The composite scores of immediate physical environment, general hospital environment, and staff interactions were positively associated with the score of overall satisfaction.	A 36-bed tertiary care medical ward in a 750-bed teaching hospital in Calgary, Alberta, Canada	21 patients who completed both pre- and post-move surveys
Ko, H. H., Zhang, H., Telford, J. J., & Enns, R. (2009). Factors influencing patient satisfaction when undergoing endoscopic procedures. <i>Gastrointestinal Endoscopy, 69</i> (4), 883-891.	Perception of the physical environment	Questionnaire - One question: How would you rate the physical environment of the exam room (cleanliness, privacy, noise level)? 5 point, poor-excellent	Patient satisfaction with endoscopy	American Society for Gastrointestinal Endoscopy modified Group Health Association of America patient satisfaction survey (mGHAA-9), 9 items, 6 aspects of endoscopic experiences: waiting time for an appointment, waiting time before procedure, personal manner (courtesy respect, sensitivity, and friendliness) of the physician, personal manner of nurses and supporting staff, technical skills (thoroughness, carefulness, competence) of physician, adequacy of explanation of the procedure; 3 questions, overall rating of the visit (5 point, very satisfied to very dissatisfied, converted to two groups-- "very satisfied" and "not very satisfied"), whether the patient would have the procedure done by the same physician or at the same facility (yes/no)	Correlational study	Factors contributing to patient satisfaction with endoscopy included personal manner of endoscopists and nurses, perception of endoscopist's technical skill, environment of the endoscopy unit, and longer time spent with physician explaining the procedure.	A tertiary academic hospital	261 patients undergoing endoscopic procedures

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Krueckeberg, H. F., & Hubbert, A. (1995). Attribute correlates of hospital outpatient satisfaction. <i>Journal of Ambulatory Care Marketing</i>, 6 (1), 11-43.	Facility attributes	Facility attributes as rated by patients using a questionnaire format (e.g. cleanliness, attractiveness, comfort)	Patient satisfaction	- Self expressed appraisal (one question, 5-point Likert Scale); - Calculated appraisal (weighted average of 75 individual hypothesized predictors on a 5 point scale in six categories (access, facility, process/systems, communication, instrumental cure, affective care), average scores	Correlational study using regression analysis	Facility attributes (cleanliness, attractiveness, comfort) were significant predictors of the variation in outpatient satisfaction. Five of eight facility attributes (e.g. comfort, convenience, attractiveness, lighting, equipment) were rated lower than average.	An acute care community hospital	474 outpatients who recently visited the departments of radiology, laboratory, cardio-respiratory therapy
Leather, P., Beale, D., Santos, A., Watts, J., & Lee, L. (2003). Outcomes of environmental appraisal of different hospital waiting areas. <i>Environment & Behavior</i>, 35 (6), 842-869.	Waiting room environment	New design with healing features (wooden chairs, nature photography, indoor plants, open-plan reception area, no files or paperwork visible from waiting area, etc.) vs. traditional design (plastic-covered chairs, small dried flower arrangement, enclosed reception area, files and paperwork visible from waiting area, etc.)	Patient satisfaction with the room environment; Patient's affective appraisals; Self-reported stress and arousal; Pulse rate	- Patient satisfaction ratings on a 7-point scale, single item (interview); - Fisher's (1974) Perceived Environmental Quality Index (PEQI), 14 seven-point scales; - Cox and Mackay's (1985) Stress Arousal Checklist (SCAL), 12 items related to stress, 8 items related to arousal, each item scored as 0/1 based on presence/absence of feelings, scale score was the sum of all items; - Pleasantness of ten specific design features rated on 7-point scale; - # of heart beats per minute (digital exercise pulse monitor[Elexis Pulse Coach 3] via clip on earlobe)	Before-after study, independent groups	The new waiting room with healing features demonstrated higher self-reported satisfaction with the environment, more positive affective appraisals, and improved stress and arousal level.	A neurology outpatient clinic in UK	145 neurology outpatients
Lee, D. W., Chan, A. C., Wong, S. K., Fung, T. M., Li, A. C., Chan, S. K., ...Chung, S.C. (2004). Can visual distraction decrease the dose of patient controlled sedation required during colonoscopy? A prospective randomized controlled trial. <i>Endoscopy</i>, 36 (3), 197-201.	Audio/visual distractions	Audio distraction - classical music; Visual distraction - home-made movie (mainly scenic views) provided by an Eyetrek system (Olympus, Japan)	Sedation use; Complications; Recovery time; Pain score; Satisfaction score; Willingness to use the sedation mode again	Doses of patient controlled propofol and alfentanil used (mg/Kg); Episodes of hypotension (systolic blood pressure <90 mm Hg) and oxygen desaturation (SaO ₂ <90%); Recovery time (patients assessed every 5 minutes until patient was orientated to time, place, and person and was able to serially subtract 7 from 100; Pain score (10 cm visual analog scale, 0 =no pain, 10 = very painful); Satisfaction score (10 cm visual analog scale, 0 =not satisfied, 10 = very satisfied); Willingness to repeat the same mode of sedation (immediately and 24 hours after, number of patients)	Randomized controlled trial, comparison of three conditions: - visual distraction; - visual and audio distraction - no distraction	Patients who had access to the visual or audiovisual distractions were more satisfied and were more willing to use the same mode of sedation again. Patients in the audiovisual group used lower doses of propofol than other two groups.	A hospital in Hong Kong	165 patients undergoing elective colonoscopy

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Lee, D.W.H., Chan, K.W., Poon, C.M., Ko, C.W., Chan, K.H., Sin, K.S....Chan, A.C. (2002). Relaxation music decreases the dose of patient-controlled sedation during colonoscopy: A prospective randomized controlled trial. <i>Gastrointestinal Endoscopy</i> , 55 (1), 33-36	Music	Music: music (classical, jazz, popular, Chinese opera) provided by a portable player with headphones and controlled by patients;	Sedation use; Complications; Recovery time; Pain; Satisfaction; Willingness to use the sedation mode again	- Doses of patient controlled propofol used (mg/Kg), - Episodes of hypotension (systolic blood pressure <90 mm Hg)and oxygen desaturation (SaO ₂ <90%), - Recovery time (patients assessed every 5 minutes until patient was orientated to time, place, and person and was able to serially subtract 7 from 100; - Pain score (10 cm visual analog scale, 0 =no pain, 10 = very painful); - Satisfaction score (10 cm visual analog scale, 0 =not satisfied, 10 = very satisfied); - Willingness to repeat the same mode of sedation (immediately and 24 hours after, number of patients)	Randomized controlled trial, comparison of three conditions: - patient-controlled sedation (PCS) and music - PCS only - music only	Patients in condition 1 (PCS + music) used significantly lower dose of sedation and were more satisfied than patients in condition 2 (PCS only). PCS + music was the best-accepted sedation mode.	A hospital in Hong Kong	165 outpatients undergoing elective colonoscopy
Nguyen Thi, P. L., Briancon, S., Empereur, F., & Guillemin, F. (2002). Factors determining inpatient satisfaction with care. <i>Social Science & Medicine</i> , 54 (4), 493-504.	Sociodemographics Health characteristics Hospital stay characteristics Unit characteristics	Sociodemographics (age, education, family situation, sex, living alone, occupational activity, distance from home to hospital, community size) Health characteristics (body mass index, Karnofsky index, assistance needed at hospital, self-perceived health status in 6 dimensions - physical functioning, bodily pain, general health perception, vitality, social functioning, mental health [SF-36 Health Profile Questionnaire]) Hospital stay characteristics (prior hospitalization, hospital choice, type of service, specialty, # of patients in a room [1 vs. 2,3], length of stay, time between discharge and completion of survey) Unit characteristics (# of inpatients, mean length of stay, # of physicians and nurses, index of care load - # of inpatients per physician/nurse per year [from administration data])	Patient satisfaction	- Patient Judgments of Hospital Quality questionnaire (PJHQ): 8 questions of explanatory variables (# of prior hospitalization, prior consultations, choice of hospital, # of beds in room, self reported condition at admission, need for assistance); 36 questions covering 5 hospital practices - admission (4), nursing and daily care (10), medical care (4), information (6), hospital environment and ancillary staff (12); 2 questions about overall satisfaction; 2 questions about intention of recommending the hospital or returning; 1 open-ended question for comments/suggestions; 5-point Likert scale, mean scores used in regression analysis	Correlational, regression analysis	Patients in private rooms reported higher satisfaction level in the following dimensions: admissions, hospital environment and ancillary staff, information, overall quality of care, recommendations/intentions. Older age and better self-perceived health status were two strongest predictors of satisfaction in all dimensions. Other predictors included family status, Karnofsky index, self-perceived condition at admission, choice of hospital, length of stay.	12 medical and surgical services in a public hospital in northern France	533 inpatients
Potthoff, J. K. (1995). Adolescent satisfaction with drug/alcohol treatment facilities: Design implications. <i>Journal of Alcohol and Drug Education</i> , 41 (1), 62-73	Aesthetics/overall atmosphere	Two facilities (A, B) were renovated dormitories, institutional character, lack of comfort, mismatch of furnishings, absence of items making a place feel like home. One facility (C) designed for adolescent care , quality furnishings and finishes of light colored woods, jeweled-tined upholstery wall-to-wall carpeting, framed prints and artwork	Patient satisfaction with interior space	Questionnaire - Questions including pieces of furniture most used, most liked and disliked places to be, what the patient most missed from home. Daily record chart - Brief notations of where the patient spent the time and how the patient was comfortable in the space.	Concurrent comparison	Patients in facility C were more satisfied with the interior space. 95% and 90% of patients in facilities A & B requested changes in their bedrooms. 60% of patients in facility C did not request changes in the bed room.	Three inpatient drug and alcohol rehabilitation treatment facilities in Midwest	41 adolescent patients (33 male, 8 female)


Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Rice, G., Ingram, J., & Mizan, J. (2008). Enhancing a primary care environment: A case study of effects on patients and staff in a single general practice. <i>British Journal of General Practice</i> , 58 (552), 465-470.	Primary care facility	Purpose-built facility vs. converted Victorian house (the old building was cramped and noisy, lacked privacy, had basic level of comfort and decoration; the new building was more spacious, had more light, more mordent appearance, and greater comfort and novel art works)	Patient satisfaction with waiting room and consultation room; Patient satisfaction with doctor communication; Patient anxiety;	- Patient satisfaction score, 5-point scale (summation of 9 items for waiting room and 6 items for consultation room); - Doctor satisfaction, 7-point scale (summation of 6 items); - Spielberger State-Trait Anxiety Inventory (STAI), 4-point scale (summation of 6 items).	Before and after comparison; repeated measurements	Patient satisfaction with the reception/waiting area and consultation rooms and satisfaction with doctor communication were higher in the new building. Lower patient anxiety was found in the new building.	An urban primary care facility in UK	1118 pre-move and 954 post-move patients;
Routhieaux, R. L., & Tansik, D. A. (1997). The benefits of music in hospital waiting rooms. <i>Health Care Supervisor</i> , 16(2), 31-40.	Music	A seven-disc compact disc player, an amplifier, and a speaker system. Low relaxing music (tempo between 60 and 80 beats per minute)	Waiting room visitor stress and perception of service quality	- A questionnaire including self-reported measures of visitor stress levels - average stress measure (anxious, nervous, tense) and average relaxation measure (at ease, calm) based on Spielberger State Anxiety Measure, 5-point scale from not at all to extremely, average scores; - Perceptions of customer service - overall rating of customer service, extent to which hospital is meeting expectation	Interventional study, music was played in randomly selected weeks	Visitors were less stressed and more relaxed when the music was played. Respondents with higher relaxation measure scores rated the service more favorably than respondents with low relaxation measure scores.	A large hospital in southwestern U.S.	297 visitors in the waiting room who were waiting for persons undergoing surgery (162 for the music condition, 135 for the no music condition)
Schmock, B. N. (2009). Effect of sacred space environment on surgical patient outcomes: A pilot study. <i>International Journal for Human Caring</i> , 13 (1), 49-59.	Aesthetics	Sacred environment, a caring-healing environment--dimmed lights with only peripheral lighting, selective music for surgical patients. Room temperature between 68F and 75F, warm blankets, and an art mural with soothing colors of nature	Patient evaluation of physical environment Patient perceived nursing care behavior Patient satisfaction	Questionnaire (Sacred Space Assessment Instrument [SSAI]) - Sacred Space Evaluation (SSE) score, summation of 18 items, 6 point scale, 1 strongly disagree to 6 strongly agree. - Caring Behavior Inventory (CBI-5), summation of 5 items from Adult Primary Care practices CBI-5, 6 point scale (never, almost never, occasionally, usually, almost always, always) - Satisfaction, summation of two items , 6 point scale, 1 strongly disagree, 6 strongly agree.	Concurrent comparison, post-test only design with a comparison group	Patients in the sacred environment reported more positive perception of the environment and the nursing care. But the difference in patient satisfaction was not statistically significant.	ORs in gynecologic oncology and genitourinary services in a community hospital	100 adult surgical patients
Scotto, C.J, McClusky, C., Spillan, S., & Kimmel, J. (2009). Earplugs improve patients' subjective experience of sleep in critical. <i>Nursing in Critical Care</i> , 14 (4), 180-4.	Earplug	Intervention group (used earplugs during regular night-time sleeping hours for one night) vs. control group	Patient satisfaction with sleep	- Verran-Snyder-Halpern Sleep Scale (8-item visual analogue instrument, Did not wake...woke off and on; Did not move...tossed all night; No sleep...10 h of sleep; Dissatisfied with amount of sleep...satisfied with amount of sleep; Did not fall a sleep at all;;fell asleep immediately; Dissatisfied with amount of time needed to fall asleep...satisfied with amount of time needed to fall asleep; Slept lightly...slept deeply; Awoke exhausted...awoke refreshed), administrated before noon on the day following the intervention, scored from 0 to 100, summation of scores	Quasi-experimental intervention study with random assignment of subjects	Total sleep satisfaction score was significantly better for patients in the intervention group who used earplugs to reduce disturbances of noise. The intervention group reported higher ratings on all 8 items (statistically significant difference on 7 items).	Two critical care units of a Midwestern teaching hospital	88 non-ventilated, non sedated adult patients (49 intervention / 39 control)

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Smykowski, L. (2008). A novel PACU design for noise reduction. <i>Journal of Perianesthesia Nursing, 23</i> (4), 226-229.	Patient care unit design	New design (separated pods of four patient bays; dedicated work station in each pod; wireless communication device, intercom system; patient controlled lighting; windows; chair for families; television at each bed) vs. old open floor plan (noisy, limited privacy, no windows, harsh lighting, centralized nursing station)	Patient satisfaction with noise level	Press Ganey question regarding "noise level in and around room", rating from 1 very poor to 5 very good (converted to 0-100), average score	Before and after comparison	Patients and staff expressed complaints about the noise and lack of privacy in the old unit. After the new unit was open, patient satisfaction about noise level improved considerably (no statistical tests were described).	A 400-bed private hospital in New York City.	No detailed description
Soufi, G., Belayachi, J., Himmich, S., Ahid, S., Soufi, M., Zekraoui, A., & Abouqal, R. (2010). Patient satisfaction in an acute medicine department in Morocco. <i>BMC Health Services Research, 10</i>, 149.	Patient room occupancy, Demographics, socioeconomics, health characteristics	Patient room occupancy (double [2 beds per room] vs. common [6 beds per room]) Other characteristics (age, gender, marital status, residence, distance from home to hospital, education level, monthly income, health insurance status, prior hospitalization, admission type, length of stay, perceived health status compared to admission & people of the same age, satisfaction with life) collected at admission and discharge	Patient satisfaction	Arabic version of EQS-H (an inpatient satisfaction questionnaire developed in France), two dimensions--quality of medical information (MI, 8 items) and relationship with staff and daily routine (RS, 8 items) collected by questionnaire interview at discharge, scores of dimensions were means of items	Correlational, regression analysis	The multivariate regression showed that higher patient satisfaction with medical information was associated with staying in double room (vs. common room), having over two prior hospitalization, longer length of stay, and better perceived health status compared to admission. Higher satisfaction in relationship with staff and daily routine was associated with longer length of stay, better perceived health status compared to admission, and satisfaction with life.	An acute medicine department in a university hospital in Morocco	214 patients (>18 yr old, length of stay at least 48 hrs)
Swan, J. E., Richardson, L. D., & Hutton, J. D. (2003). Do appealing hospital rooms increase patient evaluations of physicians, nurses, and hospital services? <i>Health Care Management Review, 28</i> (3), 254.	Patient room attractiveness	Appealing hotel-like rooms (wood furniture, decorator art, carpeted floors, crown molding, and ceramic tile baths) vs. typical rooms (metal beds, inexpensive chair, no artwork)	Patient satisfaction	Patient questionnaire (Patient Report Card [PRC]) including ten multi-item sub-scales: doctor index, nurse index, courtesy food service staff, courtesy housekeeping staff, food service satisfaction, received food ordered, food temperature, overall ratings about the hospital, intention to reuse hospital, intention to recommend hospital; rated on 5-point scale, scoring by averaging ratings of items .	Comparison of independent groups in different settings, patient groups matched on case mix, length of stay, etc.	Patients in appealing rooms were more satisfied with the hospital and more willing to reuse and recommend the hospital. Patients in appealing rooms also more positively rated attending physicians, housekeeping and food service staffs.	Two types of patient rooms in a hospital	177 patients (88 in typical rooms, 89 in appealing rooms)
Thorgaard, P., Ertmann, E., Hansen, V., Noerregaard, A., Hansen, V., & Spanggaard, L. (2005). Designed sound and music environment in postanesthesia care units - A multicentre study of patients and staff. <i>Intensive & Critical Care Nursing, 21</i> (4), 220-225.	Music	Music played through ceiling-suspended loudspeakers; Patient perception of music sound environment (pleasant/unpleasant, 10-point scale);	Patient perceived degree of relaxation (0-9); Patient satisfaction with PACU stay (0-9); Staff perception of music sound environment (pleasantness, stress, level of sound, patient experience of music environment)	Patient opinions were collected by interview and were expressed qualitatively by choosing specified statements and quantitatively on a 10-point Likert scale, 0-the best thinkable, 9-the worst thinkable); Staff opinions were collected by anonymous questionnaire and expressed qualitatively.	Correlational study	The majority of patients perceived the sound environment to be pleasant. Patients' positive perceptions of the music environment was strongly related to high level of relaxation and positive views of PACU stay. Staff had equally positive attitude towards the music environment but their views varied significantly across different units.	Five postanesthesia care units in three Danish hospitals	325 patients and 91 staff members

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Vaaler, A. E., Morken, G., & Linaker, O. M. (2005). Effects of different interior decorations in the seclusion area of a psychiatric acute ward. <i>Nordic Journal of Psychiatry</i> , 59(1), 19-24.	Interior design	- Traditional interior design and furniture Sparse furniture, walls in grey colors, lacking pictures, no window curtains, single lamps in the ceiling 4 m high, bathroom with grey, laminated paint all over, and patient rooms with a single bed and a chair of metal tubes. - New unit that looks similar to ordinary Norwegian homes. Wainscoting on walls, colorful wallpaper and paintings; lowered ceilings and multiple lighting spots, tasteful windows curtains; wardrobes, chairs, flowers and personal items in the patient rooms; Italian ceramic tile covering the entire bathroom.	Patient satisfaction Patient symptoms, general psychopathology, function and behavior	An eight-item visual analogue scale with scores 0 -10 Positive and Negative Syndrome Scale (PANSS) for schizophrenia (17) Global Assessment Scale Split version (GAF-S), a two-item scale measuring global symptoms and functioning Brøset Violence Checklist, a six-item observer-rated scale scoring behaviors that predict imminent violence in psychiatric inpatients Staff Observation Aggression Scale-Revised (SOAS-R), measuring violent or threatening incidents	Concurrent comparison, quasi-experiment	Female patients were more satisfied with the interior of the new unit. There was no significant differences in satisfaction ratings in male patients.	The seclusion area of a psychiatric acute ward in Norway	56 consecutive patients admitted to the ward
Varni, J., Burwinkle, T., Dickinson, P., Sherman, S., Dixon, P., Ervice, J.,...Sadler, B.L. (2004). Evaluation of the build environment at a children's convalescent hospital: Development of the Pediatric Quality of Life Inventory parent and staff satisfaction measure for pediatric health care facilities. <i>Journal of Developmental and Behavioral Pediatrics</i> , 25(1), 10-20.	Parent and staff satisfaction with physical environment	Pediatric Quality of Life Inventory (PedQL) Built Environment Parent Module - two scales, 18 items: structure (14 items), facility aesthetics (4 items), answer keys from 0 "never happy" to 4 "always happy" converted to 0-100; scale score was the average of the items in the scale	Staff satisfaction with coworker relationship	PedQL Health Care Satisfaction Parent Module - 7 scales, 30 items: information (6 items), inclusion of family (4 items), technical skill (3 items), services (3 items), communication (7 items), emotional needs (4 items), overall satisfaction (3 items), answer keys from 0 "never happy" to 4 "always happy" converted to 0-100; scale score was the average of the items in the scale	Correlational study	Parents were not satisfied with the existing 30-year-old facility. Higher parent satisfaction with the built environment structure and aesthetics was associated with higher parent satisfaction with healthcare services.	A 30-year-old, 59-bed, long-term, skilled nursing facility dedicated to the care of medically fragile children with complex chronic conditions	40 parents of pediatric patients

Matrix of relationships

		Outcome	
	Variable	Patient satisfaction	Patient loyalty
Environmental feature	Physical environment attractiveness		
	Positive distractions		
	Noise		
	Acoustic ceiling tile		
	Patient room occupancy		
	Acuity-adaptable room		
	Amenities		

 Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

Patient Waiting: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environmental variable	Amenities	Features of health services that do not relate directly to clinical effectiveness but may enhance the client's satisfaction and willingness to return (Brown, Franco, Rafeh, & Hatzell, 1998)	Type of amenities (Cusack et al., 2010)	Environmental inspection/audit - Seven amenities presented in the waiting room (comfy chair, magazine and puzzle book, plasma TV, paintings on walls, views from windows, computer, potted plants) reacted to by patients on questionnaires (Cusack et al., 2010)
	Attractiveness, physical environment	Aesthetic appeal of the physical environment, including the surrounding external environment, the architectural design, facility upkeep and cleanliness, and other physical elements (Becker & Douglass, 2008)	- Physical environment attractiveness score (summation of ranks) (Becker & Douglass, 2008) - Attractiveness rating on 5-point scale (Pruyn & Smidts, 1998)	Subjective rating - Four photos of each of six facilities were presented to six university graduate students in non-design majors. The students were asked to rank the environments from most attractive (6) to least attractive (1). The ratings from all students regarding one facility were summed to create an environmental attractiveness score with a higher score reflecting a more attractive environment (Becker & Douglass, 2008). - Perceived attractiveness, measured on four attributes: atmosphere, cleanliness, spaciousness and climate on a 5-point scale by patients (Pruyn & Smidts, 1998)
	Emergency Department, layout	Spatial configuration of the ED, including treatment rooms, work stations, and other components (Hall et al., 2008)	- Distance from treatment room to work station - Solid door versus soft curtain (Hall et al., 2008)	Environmental inspection/audit - Treatment rooms were classified based on two factors: 1) the distance from treatment room to work station (distance >25 ft, <25 ft); 2) type of separation (solid door vs. soft curtain) (Hall et al., 2008)
	Information access	Patient access to information regarding ED process (time to see a doctor/consultant, blood draw) and medical and therapeutic plans (Tran et al., 2002).	- Yes versus no (Tran et al., 2002) - Before versus after (Papa et al., 2008)	Experimental manipulation - In the intervention group, ED process information and medical information were provided to each patient every 15 minutes. The control group received regular care (Tran et al., 2002) - An instructional waiting room video explaining what patients should expect during ED visits played continuously on a TV set in the waiting room (Papa et al., 2008).
	Positive distractions	A set of environmental features or conditions that have been found by research to effectively reduce stress. These features or conditions include nature and certain types of music, companion animals, laughter or comedy, and certain types of art (Ulrich, 1991).	- Yes/no, before/after art intervention (Nanda, 2010) - Visual-auditory stimuli presented on a plasma TV (Pati & Nanda, 2011)	Experimental manipulation - Art intervention included plasma TV screens showing looped video of nature scene photos, still nature photographs printed on canvas, window films with garden scenes and cloud patterns (Nanda, 2010) - Five distraction conditions as defined by types of visual and audio stimuli—slide show of nature images, virtual Ambient Art, natural aquarium, and accompanying audio (Pati & Nanda, 2011)

	Term	Definition	Metrics	Measurement method
	Rapid assessment clinic/pod/zone	An ED area for quick clinician assessment and procedures on patients whose disposal is readily apparent for whom required interventions can be quickly undertaken, and for problems that do not require prolonged assessment or decision-making. Generally adapted from existing ED space, it is a novel intervention for reducing ED waiting time (Ardagh et al., 2002; Bullard et al., 2011).	- RAC versus no RAC (Ardagh et al., 2002, Bullard et al., 2008)	Experimental manipulation - RAC operated in odd weeks and did not operate in even weeks during the study period (Ardagh et al., 2002) - ED spaces were converted to RAP (Bullard et al., 2008)
Outcome	Satisfaction, patient	Degree to which an individual regards a provider's health care service, product, or the manner in which the service or product is delivered as useful, effective, or beneficial (NLM MeSH).	- Overall satisfaction with service (Papa et al., 2008; Pruyn & Smidts, 1998)	Questionnaire - One question in the survey asked for the overall satisfaction level, 5-point Likert scale, excellent - poor (Papa et al., 2008) - Overall patient satisfaction rated on a 10-point scale (Pruyn & Smidts, 1998)
	Waiting behavior, patient	Behaviors that patients exhibit in waiting rooms (Nanda, 2010; Pati & Nanda, 2011).	- Percentage of behaviors in the following categories: attention (positive distraction, other artwork, toy, book, wall, ceiling, floor, door, window, furniture, people, themselves), physical behavior (calm, fidgety, fine movement, intense), activity (playing with toys, playing with non-toys, non-play activity/other play), location (out of seat, in seat, parent's lap), social behavior (positive interaction, negative interaction, solitary behavior) (Pati & Nanda, 2011) - Number of discrete behaviors (getting out of seat, entering waiting room, people pacing, changing seat, aggressive behavior) in three, 5-minute periods every 20 minutes (Nanda, 2010)	Observation - Behavioral observations during 20-minute windows over 12 days, snapshot at beginning of each minute, modification of an existing children's observation instrument (Handen, McAuliffe, Janosky, Feldman, & Breaux, 1998) (Pati & Nanda, 2011) - Systematic observation, behavior mapping (Nanda, 2010)

	Term	Definition	Metrics	Measurement method
	Waiting time, patient	Period of time from when a patient arrives at a clinic or ED to the time his or her consultation/treatment begins (Dexter, 1999).	<p>Actual waiting time</p> <ul style="list-style-type: none"> - EED: patient waiting time to be seen by a doctor (minute) (Ardagh et al., 2002), overall ED length of stay (minute) (Ardagh et al., 2002; Bullard et al., 2008), time from triage to bed (Bullard et al., 2008), ED time from bed to physician (Bullard et al., 2008), time from treatment room to physician (Hall et al., 2008) - Medical office: time spent in waiting room and exam room (Becker & Douglass, 2008) <p>Perceived waiting time</p> <ul style="list-style-type: none"> - Percentage of respondents who estimated waiting time in several categories, from '0-5 minutes' to 'more than 30 minutes' (Becker & Douglass, 2008) - Subjective rating from "very short" to "very long" (Papa et al., 2008) 	<p>Medical records</p> <ul style="list-style-type: none"> - Data extracted from the ED module of Patient Management System (Ardagh et al., 2002) - Actual waiting time and LOS were extracted from computerized medical records (Tran et al., 2002) - Times were recorded by physicians and retrospectively collected from existing database (Hall et al., 2008) <p>Observation</p> <ul style="list-style-type: none"> - Observer was located in waiting area and hallway outside exam rooms. Time from patient entering the practice until called into exam room by staff and time from patient entering exam room until leaving the exam room (Becker & Douglass, 2008) <p>Questionnaire</p> <ul style="list-style-type: none"> - Patient perception of how long they waited in the waiting area and in the exam room was assessed on the survey (Becker & Douglass, 2008) - In one question, questionnaire asked patients to rate the wait time on a 4-point scale from 'very short' to 'very long' (Papa et al., 2008)

Patient Waiting: Article Analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Ardagh, M. W., Wells, J. E., Cooper, K., Lyons, R., Patterson, R., & O'Donovan, P. (2002). Effect of a rapid assessment clinic on the waiting time to be seen by a doctor and the time spent in the department, for patients presenting to an urban emergency department: A controlled prospective trial. <i>New Zealand Medical Journal</i> , 115 (1157), U28.	Rapid assessment clinic (RAC)	RAC vs. no RAC (RAC was in operation in odd weeks and no RAC in even weeks during the study period)	Patient waiting time to be seen by a doctor Length of time in ED	Data extracted from the ED module of Patient Management System, minute	Quasi experimental	The waiting time to be seen by a doctor was 8-11 minutes shorter, and the length of stay in ED was 20-25 minutes shorter for patients in Triage 4 and 5 categories in RAC weeks than in no RAC weeks. No difference was found in patients in Triage 2 and 3 categories	An ED in Australia	4471 patients who attended the ED during the 10 week period
Becker, F., & Douglass, S. (2008). The ecology of the patient visit: Physical attractiveness, waiting times, and perceived quality of care. <i>Journal of Ambulatory Care Management</i> , 31(2), 128-141.	Physical environment attractiveness	Physical environment attractiveness score (summation of ranks based on subjective ratings by university students)	Patient perceived waiting time. Actual waiting time Perceived quality of care	Questionnaire - Perceived waiting time (percentage of respondents in categories from '0-5 minutes' to 'more than 30 minutes') Observation - Time from patient entering the practice until being called into exam room by staff and time from patient entering exam room until leaving the exam room, minute - Quality-of-care index: % of "excellent" responses to a question (patient questionnaire survey, 4 questions: The care I received here today was...; The service I received here today was...; Overall, my interactions with staff were...; Overall, my interactions with doctors were...);	Correlational study; cross sectional	Higher ratings of environmental attractiveness were associated with more favorable perceptions of the quality of care, a higher percentage of anxiety reduction, higher ratings of staff interactions. Significant relationships were found between patient perceptions of time and perceived overall quality and anxiety reduction. There is no direct relationship between environmental attractiveness and perceived waiting time. Patients tended to overestimate short waiting time and underestimate long waiting time.	Six outpatient facilities in New York	Six graduate students, 205 outpatients
Bullard, M, Lo, A, Latoszek, K., Holroyd, B., Rowe, B. (2008). Impact of a rapid-assessment pod on ED overcrowding measures: A randomized trial. <i>Academic Emergency Medicine</i> , 15 (5 Suppl 1), S197.	Rapid assessment pod (RAP)	Three ED standard care spaces were converted to 2 stretchers for clinician assessment and procedures and 7 chairs for patients to be transferred to receive medications, IV therapy, be observed, or wait for results	- ED length of stay - Time from triage to bed - Time from bed to physician	Medical records, minute	Experimental	Time from triage to bed was reduced significantly by 24 minutes for CTAS level 3 patients. The ED length of stay was reduced from 567 to 544 minutes although the difference was not statistically significant.	An ED in Canada	More than 6000 ED visits
Cusack, P., Lankston, L., & Isles, C. (2010). Impact of visual art in patient waiting rooms: Survey of patients attending a transplant clinic in Dumfries. <i>Journal of the Royal Society of Medicine Short Reports</i> , 1(6), 52.	Amenities for patients in clinic waiting room	Seven patient amenities: comfy chair, magazine, puzzle book, plasma TV, paintings on the walls, views from windows, computer, potted plants.	Patient preference	Questionnaire - Ratings of the importance of the seven amenities presented in the waiting area, 5-point scale, 1 not at all important, to 5 very important - Ratings of art type: landscape/nature, portraits, animals/bird paintings, abstract art.	One-shot study	The most important amenity was the comfy chairs, followed by magazines and puzzle books, plasma TV, and paintings on the walls. Views from windows, computer and potted plants were least rated. Patients preferred paintings with the contents of landscapes/nature and animals/birds.	A renal transplant unit in a UK hospital	44 patients
Hall, K. K., Kyriacou, D. N., Handler, J. A., & Adams, J. G. (2008). Impact of emergency department built environment on timeliness of physician assessment of patients with chest pain. <i>Environment and Behavior</i> , 40(2), 233-248.	ED layout	Distance from work station to treatment room (>25 ft, <25 ft) Solid door vs. soft curtain (yes/no)	Patient waiting time in treatment room	Time in minutes from placement of patient in ED treatment room to the initial physician assessment (10 min or less, >10 min), collected from existing database, recorded by physician	Correlational study	The presence of a solid door and longer distance (>25ft) from patient treatment room to work station were significant predictors of patient longer waiting time in treatment room.	ED in a large urban teaching hospital	2024 ED visits

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Nanda, U. (2010). <i>Improving the waiting experience in the emergency department: A two phase study</i>. Concord, CA: Center for Health Design.	Art intervention	The installation of: - plasma screens showing looped video of nature scene photos - still nature photographs printed on canvases - window films with garden scene and cloud pattern	Patient behavior in waiting rooms Noise level	Systematic observation, behavior mapping - continuous behaviors (reading, dosing, watching TV) annotated on floor plans with symbols for one 5-minute period every 20 minutes - discrete behaviors (getting out seat, entering waiting room, people pacing, changing seat, aggressive behavior), the number of behaviors in three 5-minute periods every 20 minutes. - behaviors were classified into three categories: distraction, non-distraction activity, restless/anxious behavior Noise measurement four times per hour, UEI DSM101 sound level meter	Before-after study	Significant decreases in restless behavior and "people watching" were found in both sites after the installation of art intervention. Noise levels and the number of front desk queries decreased; people talking increased.	ED waiting rooms at two large hospitals in Houston	60 hours of observational data (30 before and 30 after art intervention) in each waiting room
Papa, L., Seaberg, D. C., Rees, E., Ferguson, K., Stair, R., Goldfeder, B., & Meurer, D. (2008). <i>Does a waiting room video about what to expect during an emergency department visit improve patient satisfaction? Canadian Journal of Emergency Medicine, 10(4), 347-354.</i>	Patient access to information	A instructional waiting room video explaining what patients should expect during ED visits. The video was played on a TV set in the waiting room continuously.	Perceived waiting time Patient satisfaction	Questionnaire completed before discharge - Perceived waiting room time, 4-point, very short - very long - Overall satisfaction with ED visit, 5-point Likert scale, excellent - poor	Before-after study	Patients in the post-video group were significantly more satisfied with the ED visit. About 65% patients in this group rated the ED visits as excellent or good, compared to about 58% in the pre-video group. Patients in post-video group perceived a slightly shorter waiting time but the difference was not statistically significant.	ED in a tertiary care university teaching hospital	1132 patients (551 pre- and 581 post-video)
Pati, D. & Nanda, U. (2011). <i>Influence of positive distractions on children in two clinic waiting areas. Health Environments Research and Design Journal, 4(3), 124-140.</i>	Positive distractions	Visual-auditory stimuli presented on a plasma TV: - no stimuli, the control condition; - visual-static stimuli: still nature photographs in a slide show (no audio); - visual-dynamic stimuli: virtual Ambient Art (with accompanying audio); - visual-dynamic stimuli: virtual Ambient Art (without accompanying audio); - visual-dynamic stimuli: natural aquarium (with accompanying underwater sounds); - visual-dynamic stimuli: natural aquarium (without accompanying underwater sounds).	Children's activities and behaviors	Behavioral observations during 20-minute windows over 12 days, snapshot at beginning of each minute, modification of an existing children's observation instrument (Handen, McAuliffe, Janosky, Feldman, & Breau, 1998), percentage in the following categories - Attention: positive distraction, other artwork, toy, book, wall, ceiling, floor, door, window, furniture, people, themselves - Physical behavior: calm, fidgety, fine movement, intense - Activity: playing with toys, playing with no toys, nonplus activity/other play - Location: out of seat, in seat, parent's lap - Social behavior: positive interaction, negative interaction, solitary behavior	Quasi experimental	The positive distractions were significant attention grabbers. When positive distractions were turned on, patient's attention to the plasma TV greatly increased. During distraction conditions, children's calm behavior increased by 7-9%.	Patient waiting areas in dental and cardiac clinics in a major pediatric tertiary hospital	158 pediatric patients

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Pruyn, A., & Smidts, A. (1998). Effects of waiting on the satisfaction with the service: Beyond objective time measures. <i>International Journal of Research in Marketing</i> , 15(4), 321-334.	Physical environment attractiveness	Perceived attractiveness, measured on four attributes: atmosphere, cleanliness, spaciousness and climate	Actual waiting time Perceived waiting time Affect (irritation, fairness, annoyance, boredom, stress) Satisfaction with the service	Questionnaire - Appointment time recorded by patient (from appoint time to time called into physician's room) - Questions asking waiting time and time spent in waiting room, appraisal of waiting time (minute, 1 very short to 5 very long) - Questions regarding affection ratings, 5 point scale - Question about satisfaction with service, 10-point scale	Correlational study	The attractiveness of waiting rooms was positively correlated with the overall satisfaction with service and the positive affects but was not correlated with perceptions of waiting time as short or long. Actual waiting time influences satisfaction mainly through a cognitive route--perceived waiting time.	Polyclinics in three Dutch hospitals	127 men and 210 women
Tran, T. P., Schutte, W. P., Muelleman, R. L., & Wadman, M. C. (2002). Provision of clinically based information improves patients' perceived length of stay and satisfaction with EP. <i>American Journal of Emergency Medicine</i> , 20(6), 506-509.	Patient access to information	In the intervention group, a medical student provided information to each patient every 15 minutes: ED process information (waiting time to see a physician, blood draw, radiologic imaging, time to see a consultant, etc.), medical information regarding diagnostic and therapeutic plans. The control group received standard emergency care.	Patient perceived ED waiting time, ED length of stay Patient rating of staff Actual waiting time, length of stay	Interview, patients were asked to estimate waiting time and LOS, and rate staff Actual waiting time and LOS were extracted from computerized medical records	Experiment	The group of patients who periodically received process and medical information perceived length of stay in ED to be significantly shorter and rated physician significantly more favorable.	A 300-bed academic hospital in US	619 outpatients or proxy informants who visited the ED

Matrix of relationships

		Outcome		
	Variable	Patient waiting time	Patient waiting behavior	Patient satisfaction
Environmental feature	Rapid assessment clinic/pod/zone			
	Physical environment attractiveness			
	Positive distractions			
	Information access			
	Amenities			
	ED layout			

 Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

Staff Efficiency: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environmental variable	Head mounted display	A scanning retinal display that uses a laser to project a monochromatic red image onto a transparent monocle which then reflects the image on the wearer’s retina. The device keeps patients’ vital signs within view of the anesthesiologist at all times, precluding the need to look at a patient monitor (Liu et al., 2009).	Monitoring display type - Head-mounted display vs. standard monitoring equipment(a video graphics array screen mounted within the anesthesia machine) (Liu et al., 2009)	Experimental manipulation - Subjects were asked to perform simulated monitoring tasks when the HMD was used versus not used (Liu et al., 2009).
	Illumination level (illuminance)	The intensity of luminous flux (Stein, 1997).	- Bright light versus normal room lighting (Crowley et al., 2003)	Design manipulation - Bright light (BL) exposure during night shifts compared with normal room lighting. Bright light (~5000 lux) was produced by 3 light boxes (61.0 cm wide, 77.5 cm high, 12.1 cm deep, cool white fluorescent lamps, Apollo Light Systems Inc., Orem, UT) set on the perimeter of a large, round table facing the center of the table. Normal room light is about 150 lux (Crowley et al., 2003)
	Medication distribution system	A system for preparing and distributing medications for the treatment of patients in healthcare settings (Poley et al., 2004).	Medication distribution system type: - A decentralized, patient-orientated, ready-to-use drug distribution system with satellite pharmacies close to the patient units versus a ward stock system in which routinely used drugs are issued by the hospital’s central pharmacy, which is located in a neighboring building, and stored in cupboards on the wards (Poley et al., 2004)	Design manipulation - Patient units that used different medication distribution systems were compared (Poley et al., 2004).
	Music	The art of arranging sounds in time so as to produce a continuous, unified, and evocative composition, as through melody, harmony, rhythm, and timbre (The Free Dictionary)	- Type of music (activating music, deactivating music, no music) (Miskovic et al., 2008), (rock music, classic, no music) (Sanderson et al., 2005)	Experimental manipulation - Music played on a computer with a constant volume of 35 dB (Miskovic et al., 2008)

	Term	Definition	Metrics	Measurement method
	Noise	A sound that is loud, unpleasant, unexpected, or undesired (The Free Dictionary)	- Noise versus quite conditions (Moorthy et al., 2003)	Experimental manipulation - Operating theatre background noise at 80 to 85 dB (Moorthy et al., 2003)
	Nurse station layout	Spatial arrangement of nurse work stations in a nursing unit (Dutta, 2008; Gurascio-Howard & Malloch, 2007)	- Types: decentralized versus centralized (Dutta, 2008; Gurascio-Howard & Malloch, 2007)	Design manipulation - New unit with 9 decentralized nursing stations versus old unit with 2 centralized nursing stations (Dutta, 2008) - Centralized nurse station design (one centralized station in unit) versus decentralized nurse station design (12 alcoves near patient rooms) (Gurascio-Howard & Malloch, 2007) - Two units in each of three hospitals: one with a centralized nursing station design and the other with a decentralized nursing station design (Zborowsky et al., 2010)

	Term	Definition	Metrics	Measurement method
	Nursing unit shape/layout	Spatial arrangement of patient care rooms and nursing stations in nursing units (Donahue, 2009; Shepley, & Davies, 2003; Trites et al., 1970).	<ul style="list-style-type: none"> - Type of unit design: pod design; circular, rectangular; racetrack (Donahue, 2009; Shepley, & Davies, 2003; Trites et al., 1970) - Linear integration (space syntax) (Hendrich et al, 2009) 	<p>Design manipulation</p> <ul style="list-style-type: none"> - Pod design (A nursing unit was divided into four pods. Each covered 100 feet, two per hallway. Each served eight rooms and was staffed by two RNs) versus a racetrack design (two, 200-foot parallel hallways, with 20 beds along one hallway and 18 beds along the other; patient rooms on the outer sides, a central nursing station, utility room, and patient kitchen between hallways; three pathways connect the long hallways). (Donahue, 2009) - Dense radial configuration (circular design with patient rooms radiating around the circumference and a nurse station at the center, 10 beds, 8,100 SF, 2 nurses, carpeted, with low-volume radio) versus double-corridor rectangular/racetrack (nurse station/support space in the core, patient rooms on the perimeter wall, 24 beds, 18,500 SF, 5-10 nurses, resilient flooring) (Shepley, & Davies, 2003) - 12 units, three types of layout, four units in each type: radial, single-corridor rectangular, double-corridor rectangular (Trites, et al, 1970) <p>Measurement using architectural drawings and computer software</p> <ul style="list-style-type: none"> - Linear integration (a measure of the centrality of a space with respect to the entire layout). The integration of a space such as a patient room is computed by mapping the layout of the space onto a unique network of straight lines representing potential movement paths through it. Each space then maps onto one or more individual lines that pass through it; distances between spaces are described as the number of intermediate lines between them (Hendrich, et al, 2009).
	Patient room layout	Spatial arrangement of architectural elements and equipment in patient rooms (Pati et al, 2010).	<ul style="list-style-type: none"> - Direction of approach to the patient (right-handed, left-handed, and neutral-handed configurations) - The presence or absence and location of an intravenous (IV) line to the patient, using a mobile pole (IV pole on patient's left, on patient's right, and no-IV pole) (Pati et al, 2010) 	<p>Experimental manipulation</p> <ul style="list-style-type: none"> - Nine experimental conditions defined by three directions of approach to the patient and three conditions of IV pole location (Pati et al, 2010)

	Term	Definition	Metrics	Measurement method
	Patient room occupancy	Number of patients per patient room--one per room (single room, private room), two (double room), four-bed room, multi-bed open bays (Shepley, 2002).	New open NICU vs. old unit with 1-5 bed patients rooms (Shepley, 2002)	Existing data from medical or administrative records - Old NICU: six rooms for 1-5 beds each vs. New remodeled NICU: open unit (Shepley, 2002)
	Pharmacy equipment	Fixtures and equipment used in the pharmacy area for the purpose of preparing and distributing medications (Lin et al., 1988).	Pharmacy equipment type - Baker drug counter, Systamodule pharmacy fixture, exiting equipment (Lin et al., 1988)	Experimental manipulation - Simulated experiments were conducted in four conditions: baseline—existing layout, Baker drug counter, Systamodule pharmacy fixture, both Baker drug counter and Systamodule pharmacy fixture (Liu et al., 2009)
	Wireless technology	Technology enabling the transfer of information over a distance without the use of electrical conductors or wires (Guarascio-Howard, 2011; O'Connor et al., 2009).	Communication system type - The addition of a wireless device for nurse communication with display and audio versus traditional communication infrastructure using nurse call system, telephones, health unit coordinator (HUC) stations (Guarascio-Howard, 2011) - Wireless e-mail over a GSM cellular network using handheld devices versus baseline (receive-only numeric pagers, overhead paging, physical searches for staff, handwritten messages left in or near patient charts, and e-mail accessed by computers) (O'Connor et al., 2009)	Design manipulation - A wireless device was added to the existing communication system to help nurses receive team communications and alarms (Guarascio-Howard, 2011) - The installation of a wireless e-mail system using a GSM cellular network and handheld devices (O'Connor et al., 2009)
	Workroom layout	Spatial arrangement of equipment in a workroom (Lu & Hignett, 2009).	Spatial layout of soiled workroom (Lu & Hignett, 2009)	Measurement on architectural drawings - Examination of the location of equipments in floor plans (Lu & Hignett, 2009)

	Term	Definition	Metrics	Measurement method
Outcome	Circadian misalignment	A mismatch between an individual's desired bedtime and the timing of his/her circadian system. Often observed among shift workers and individuals suffering from jet-lag. Usually occurs when individuals attempt to initiate sleep at sub-optimal times during their circadian cycles and, consequently, experience sleep disturbances (Jean-Louis et al, 2008).	<ul style="list-style-type: none"> - DLMO (dim light melatonin onset) based on melatonin level obtained through saliva sampling and radioimmunoassay analysis - Temperature minimum (Tmin) - Amount of re-entrainment (Crowley et al., 2003) 	<p>Saliva sampling and radioimmunoassay analysis</p> <ul style="list-style-type: none"> - Saliva sampling and radioimmunoassay analysis to determine DLMO, Tmin (DLMO + 7 hr), and amount of re-entrainment (not re-entrained [Tmin before the daytime dark/sleep period], partially re-entrained [Tmin during the first half of dark/sleep], or completely re-entrained [Tmin during the second half of dark/sleep]) (Crowley et al., 2003)
	Medication processing time	Amount of time from when a prescriber orders medication, to the pharmacy receiving the order, to the pharmacist completing the order (Wietholter et al, 2009).	<ul style="list-style-type: none"> - Prescription filling time (Lin et al, 1988; Wietholter et al, 2009) - Pharmacist travel distance for filling prescriptions (Lin et al, 1988) 	<p>Computer simulation</p> <ul style="list-style-type: none"> - Prescription filling time measured by computer simulation using a predetermined motion time system (PMT systems), standards determined through consultation with supervising pharmacist and videotaping of pharmacist work (Lin et al, 1988) <p>Medical records</p> <ul style="list-style-type: none"> - Review of medication records (Wietholter et al, 2009) <p>Measurement on architectural drawings</p> <ul style="list-style-type: none"> - Pharmacist travel distance for filling prescriptions was measured and calculated using architectural drawings (Lin et al, 1988)
	Nurse response to patient call	Amount of time from when a nurse call button is pressed to when the nurse responds to the call (Guarascio-Howard, 2011)	<ul style="list-style-type: none"> - Response time to patient calls (minute) (Guarascio-Howard, 2011) - Patient ratings of nurse response to calls (Donahue, 2009) 	<p>Observation</p> <ul style="list-style-type: none"> - Shadowing of nursing activity (Guarascio-Howard, 2011) <p>Questionnaire survey</p> <ul style="list-style-type: none"> - Press Ganey score on nurses' promptness in response to patient calls (Donahue, 2009)

	Term	Definition	Metrics	Measurement method
	<p>Staff travel (Time allocation, travel distance)</p>	<p>Physical movements (location, time, duration, frequency, activity type) of healthcare staff members (Shepley, 2002; Zborowsky, 2010).</p>	<ul style="list-style-type: none"> - Nursing activity (20 types), location (31), time data, and nurse type were recorded sequentially (Shepley, 2002) - Frequency and duration of activities (Zborowsky, 2010) - Nurse walking distance (steps per minute, the ratio of travel distance to unit floor area) (Shepley, 2002) 	<p>Observation</p> <ul style="list-style-type: none"> - Observers made rounds of the facility at specific time points and recorded activities. Staff activities were classified in 9 categories (e.g., direct patient care, indirect patient care, nonproductive time), locations in 5 categories (e.g., nurse station, patient room), and 2 other categories (with patient, total not travel) (Trites et al, 1970) - Behavior mapping (recording staff behaviors, locations, time data) (Shepley, 2002) - Videotaping using ceiling-mounted cameras received and processed by custom-made software installed on computers (Pati, Cason, Harvey, & Evans, 2010). - Frequency and duration of activities recorded by a digital timer and visual data charts (Zborowsky, 2010) <p>Work sampling study with PDAs</p> <ul style="list-style-type: none"> - The PDAs were set to vibrate randomly approximately 22 times over a 12-hour period. The nurse then selected her or his location and the most accurate description of the activity being performed (Donahue, 2009) - A personal digital assistant (PDA) vibrated at random times throughout the work shift, prompting nurses to select their location and activity at that moment from a predetermined list of options (Hendrich et al., 2009) <p>Pedometer</p> <ul style="list-style-type: none"> - Electronic pedometer attached to the back of staff's belts (Shepley & Davies, 2003) (Donahue, 2009) <p>Indoor positioning system</p> <ul style="list-style-type: none"> - An positioning system tracked radio-frequency identification (RFID) badges worn by participating nurses (Hendrich, 2009) <p>Link analysis</p> <ul style="list-style-type: none"> - Link analysis was used to record and analyze movements among components, i.e., nursing staff, equipment/devices, and furniture. Tasks that occupied the most space, areas that had the highest level of activity (to determine the layout and adjacency requirements of equipment and furniture), and areas needing easiest access were identified (Lu, 2009)

	Term	Definition	Metrics	Measurement method
	<p>Surgeon/anesthesiologist performance</p>	<p>Performance of surgical tasks and anesthesia monitoring tasks (Liu et al., 2009; Miskovic et al., 2008; Sanderson, 2005).</p>	<p>Anesthesiologist performance</p> <ul style="list-style-type: none"> - Number of anesthesia events detected, event detection time(s), frequency of changes in gaze location (changes/minutes), percentage of time looking toward a location - Percentage of correct judgments (abnormality judgments: normal, high, low; trend judgments: steady, increasing, decreasing, fluctuating) (Sanderson, 2005) - Anesthesiologist perception of work efficiency (Liu et al., 2009) <p>Surgeon performance</p> <ul style="list-style-type: none"> - Global task score (the anatomy scores [accuracy of cystic duct and artery clipping] minus the error score [e.g., clipping errors, cutting errors, bleeding], with a minimum score of 0), total task time, instrument travel distances, and surgeons' heart rate (Miskovic et al., 2008) 	<p>Simulation</p> <ul style="list-style-type: none"> - Test scenarios performed on a METI ECS™ (Sarasota, FL) mannequin. Video data were analyzed to determine the onset time of an event (when event symptoms are first visible in the video) and the time of detection (when the participant makes a comment about the event or begins a corrective action). Gaze location was coded using three categories: Anesthesia machine, Patient, and Other (Liu et al., 2009) - LS500 (Xitact) virtual patient laparoscopy simulator, run by a Pentium PC with a high-resolution thin film transistor (TFT) monitor connected to 2 robotic force feedback devices acting as interfaces for the laparoscopic instruments (Miskovic et al., 2008). - The surgical task was to move cylindrical pieces of sponge from one disc to another. Surgical performance was measured by the Imperial College Surgical Assessment Device. When motion tracking sensors attached to the dorsum of both hands move in an electromagnetic field generated by the system, the positional data from the trackers gets converted into data on the number of movements and the path length traversed by each hand using specially developed software (Moorthy et al., 2003). - During simulated monitoring of visual and auditory displays of patients' vital signs (9 anesthesia test scenarios), participants were asked every 50–70 seconds whether one of five vital signs was abnormal and the trend of its direction. Anesthesia simulator (Advanced Simulation Corporation's Body TM physiological and pharmacological engine, connected to an interface largely similar to the Body TM Anesthesia Simulator interface) (Sanderson, 2005). <p>Questionnaire</p> <ul style="list-style-type: none"> - Self-reported work efficiency (Liu et al., 2009)

	Term	Definition	Metrics	Measurement method
	Team communication	Frequency, formalization, structure, and openness of information exchange between team members (Carmeli, Gelbard, & Goldrieck, 2010)	<ul style="list-style-type: none"> - Number of verbal interactions per hour, length of conversations, number of persons involved in one interaction (Dutta, 2008) - Number of nurse-initiated communications (Guarascio-Howard, 2011) - Communication type, number, time (Guarascio-Howard & Malloch, 2007) - Staff perception of communication (Guarascio-Howard & Malloch, 2007; O'Connor et al., 2009) - Communication between nurse and surgeon (response rate, correct patient ID time, error rate, response time, solution time, communication time, intraoperative case interruptions) (Ortega et al., 2009) 	<p>Observation</p> <ul style="list-style-type: none"> - Staff verbal interactions were manually recorded according to predetermined categories for physical location, participant roles, gender and duration of interactions (Dutta, 2008) - Shadowing of nurses (Guarascio-Howard & Malloch, 2007) - Direct observation with stop-watch (Ortega et al., 2009) <p>Audio recording</p> <ul style="list-style-type: none"> - Analysis of audiorecording of team communication (Guarascio-Howard & Malloch, 2007) <p>Interview</p> <ul style="list-style-type: none"> - Interviews regarding staff's perceptions on communication, technology, and teamwork (Guarascio-Howard & Malloch, 2007) <p>Questionnaire</p> <ul style="list-style-type: none"> - Questionnaire, 49 items, developed by interview, focus group, pretesting. Items included: improved speed of communication, improved reliability of communication, less effort required to communicate, improved physician response times to critical issues, etc. 7 point scale (O'Connor et al., 2009).

Staff Efficiency: Article Analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Crowley, S. J., Lee, C., Tseng, C. Y., Fogg, L. F., & Eastman, C. I. (2003). Combinations of bright light, scheduled dark, sunglasses, and melatonin to facilitate circadian entrainment to night shift work. <i>Journal of Biological Rhythms</i> , 18 (6), 513-523.	Interventions to reduce circadian misalignment (Bright light during night shift, dark sunglasses during daytime, and melatonin before sleep)	6 combinations of interventions including the fixed daytime dark/sleep (D/S) schedule, normal sunglasses (N SG), dark sunglasses (D SG), bright light (BL) during the night shifts, and melatonin (M) before daytime sleep.	Re-entrainment: phase-shifting circadian rhythms to align with night work and day sleep schedules	- DLMO (dim light melatonin onset) based on melatonin level obtained through saliva sampling and radioimmunoassay analysis - Temperature minimum (Tmin). DLMO + 7 hr - Amount of re-entrainment (not re-entrained [Tmin before the daytime dark/sleep period], partially re-entrained [Tmin during the first half of dark/sleep], or completely re-entrained [Tmin during the second half of dark/sleep])	Experiment	Circadian misalignment in nightshift workers may cause sleep disorders, fatigue, gastrointestinal disturbances, impaired performance, and diminished job and public safety. With bright light during the night shift, almost all of the earlier participants achieved complete re-entrainment (baseline Tmin > 0700). With only room light during the night shift, darker sunglasses helped earlier participants phase-delay more than normal sunglasses, but melatonin did not increase the phase-delay.	A research lab	67 participants
Donahue, L. (2009). A pod design for nursing assignments: Eliminating unnecessary steps and increasing patient satisfaction by reconfiguring care assignments. <i>American Journal of Nursing</i> , 109 (11 Suppl), 38-40.	Pod design of nursing unit	A nursing unit was divided into four pods, each covered 100 feet, two for each hallway. Each had eight rooms—with 10 beds each in pods A and B and nine beds each in pods C and D. Each was served by two RNs. The old unit included two 200-foot parallel hallways, with rooms totaling 20 beds along one hallway and 18 beds along the other. Patient rooms are only on the outer sides of the hallways with a central nursing station, a utility room, and a patient kitchen between hallways. Three pathways connect the long hallways.	Nurse activity Nurse traveling Patient satisfaction	- Spaghetti diagram - Behavior observation with PDAs and work sampling study. The PDAs were set to vibrate randomly approximately 22 times over a 12-hour period. The nurse then selected her or his location and the most accurate description of the activity being performed. - Pedometer - Press Ganey score on nurses' promptness in response to calls, nurses' attention to patient's special and personal needs, nurses keeping patients informed, and overall nursing care received (% of satisfied patients) - Patient complaints (verbally communicated patient or family concern or issue that can be resolved quickly by the staff, whereas a grievance is a written or verbal complaint that was not resolved at the time it occurred).	Before-after study	The spaghetti diagram showed an improved, less erratic work flow. The number of steps the nurse had to take decreased significantly, from 1075 to 877 steps in four hours and from 3928 to 2,291 steps in eight hours. The amount of time spent in direct patient care and time devoted to value-added care—patient-centered actions that directly benefit the patient increased. Patient satisfaction increased while the number of patient complaints decreased.	A 38-bed cardiothoracic and vascular surgery unit in a major hospital in PA	One nurse for Spaghetti diagram and pedometer.
Dutta, R. (2008). Influence of nursing unit layout on staff communication and interaction patterns. Unpublished Master's thesis, Cornell University.	Decentralized vs. centralized nursing station layout	New unit with 9 decentralized nursing station layout vs. old unit with 2 centralized nursing stations	Staff communication	Systematic observations of opportunistic or unplanned communication frequencies and behaviors. Staff verbal interactions were manually recorded according to predetermined categories for physical location, participant roles, gender and duration of interactions. - # of verbal interactions per hour - Length of conversations - # of persons involved in one interaction	Before-after study	There were significant decreases in the number of verbal interactions between staff members in nursing pods and corridors in the decentralized unit. There were 50% fewer conversations across all the duration categories and the number of two person interactions fell by around 57% while those involving 3 and 4 fell by 60% and 81%, respectively, in the new unit.	An intensive cardiac care unit in a 204-bed hospital	23 hours (994 data sets) in old unit, 50 hours (899 data sets) in new unit

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Guarascio-Howard, L. (2011). Examination of wireless technology to improve nurse communication, response time to bed alarms, and patient safety. <i>Health Environments Research and Design Journal, 4(2), 109-120.</i>	Wireless communication technology	Before: a nurse call system and telephones located at each decentralized nurse station and health unit coordinator (HUC) station; nurse badges tracked and monitored at the HUC master station; nurse response depended on HUC response time and/or the ability to see the call light. After: Adding a wireless device for nurse communication with display and audio for the reception of team communications and alarms regarding bed exit and bed status changes	Nurse response to patient call Team communication	Observation. Shadowing of nurse activity. - Response time to patient calls (minute) - Number of nurse-initiated communications (number)	Before-after study	Nurse response time to patient calls significantly improved (reduced). Both nurse-initiated and team-initiated communication increased. The percentage of nurse-initiated communication increased. An increase in communication episodes among caregivers adds to the efficiency of patient care by providing additional opportunities to clarify expectations and patient orders.	A medical-surgical unit in a Southwestern U. S. hospital	4 RNs
Guarascio-Howard, L., & Malloch, K. (2007). Centralized and decentralized nurse station design: An examination of caregiver communication, work activities, and technology. <i>Health Environments Research and Design Journal, 1(1), 44-57.</i>	Nurse station layout	Centralized nurse station design (one centralized station in unit) Decentralized nurse station design (12 alcoves near patient rooms)	Nurse activity Nurse perception of communication	Observation. Shadowing of nurse activity. - Care activity type (direct care--RN care to patient in patient's room or hallway providing medications, bath, shower, or responding to alarms and emergencies, indirect care, medication). Activity (report, charting, etc.). - Communication type, number, time - RN locator system Patient satisfaction survey data - Promptness in response to call Audio recording of team communication Interview focusing on communication, technology, and teamwork	Concurrent comparison	The decentralized RN spent greater time for all communication types except patient information. More total time was spent with patient care activities and in the patients' rooms by decentralized RNs. Patient satisfaction survey data showed that the decentralized unit scored higher on the question "promptness in response to call"	Two medical-surgical units at two hospitals (differences in patient care delivery models, RN assignments, types of technology, and computerization)	8 RNs, 4 in each unit
Hendrich, A., Chow, M. P., Bafna, S., Choudhary, R., Heo, Y., & Skierczynski, B. A. (2009). Unit-related factors that affect nursing time with patients: Spatial analysis of the time and motion study. <i>Health Environments Research and Design Journal, 2(2), 5-20.</i>	Spatial properties of the nurse assignment--Linear integration (a measure of the centrality of a space with respect to the entire layout)	The linear integration of each nurse assignment was computed by averaging the integration values of each room in the assignment. The linear integration of a space (such as a patient room) is computed by mapping the layout of the space onto a unique network of straight lines representing potential movement paths through it. Each space then maps onto one or more individual lines that pass through it; distances between spaces are described as the number of intermediate lines between them.	Nurse activity (time motion)	-Nurse movement. An indoor positioning system that tracked radio-frequency identification (RFID) badges worn by participating nurses - Distance traveled. Validated by a specialized armband worn by a subset of study nurses that collected physiology and motion data - A personal digital assistant (PDA) that vibrated at random times throughout the work shift, prompting nurses to select their location and activity at that moment from a predetermined list of options.	Correlational study, cross sectional	The integration value of nurse assignment was positively related to the number of entries to patient rooms, as well as entries to the nursing station. It is possible that increased entries to patient rooms contribute to improved patient surveillance, and potentially a decrease in failure-to-rescue. Number of entries to patient rooms was positively associated with total time spent in patient rooms. Assignments with higher centrality (integration) may allow nurses the flexibility to make more trips to patient rooms as well as nurse stations thus enhance team communication.	36 diverse hospitals in U.S.	767 medical-surgical nurses, 2,201 nursing shifts, totaling almost 22,000 work hours

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Lin, A. C., Barker, K. N., Hassall, T. H., & Gallelli, J. F. (1988). Effects of simulated facility- design changes on outpatient pharmacy efficiency. <i>American Journal of Hospital Pharmacy</i> , 45(1), 116-121.	Pharmacy furniture/equipment	Baker drug counter, Systamodule pharmacy fixture Four conditions: - Baseline--existing layout - Simulated layout with Baker drug counter - Simulated layout with Systamodule pharmacy fixture - Simulated layout with both the above	Pharmacist efficiency	- Prescription filling time measured by computer simulation using a predetermined motion time system (PMT systems), standards determined through consultation with supervising pharmacist and videotaping of pharmacist work - Pharmacist travel distance for filling prescriptions, measured and calculated using architectural drawings	Experiment, simulated	The use of the drug counter and pharmacy fixture reduced the prescription filling time by 0.123 to 0.280 minutes per prescription. The average pharmacist travel distance was reduce by 102 feet to 14 feet.	An outpatient pharmacy in a 504-bed government hospital	5 pharmacists; 635 randomly sampled prescriptions
Liu, D., Jenkins, S. A., Sanderson, P. M., Watson, M. O., Leane, T., Krays, A., & Russell, W.J. (2009). Monitoring with head-mounted displays: Performance and safety in a full-scale simulator and part-task trainer. <i>Anesthesia & Analgesia</i> , 109 (4), 1135-1146.	Head-mounted displays (HMDs) which keep patients' vital signs within view of anesthesiologist at all times, even while performing procedures or unable to see the monitor	HMD vs. standard monitoring alone (a video graphics array screen mounted within the anesthesia machine)	Anesthesiologist speed of detecting patient-related events Anesthesiologist perception of work efficiency	35– 40-min test scenarios performed on a METI ECS™ (Sarasota, FL) mannequin. Video data were analyzed to determine the onset time of an event (when event symptoms are first visible in the video) and the time of detection (when the participant makes a comment about the event or begins a corrective action). Gaze location was coded using three categories: Anesthesia machine, Patient, and Other - Number of events detected - Event detection time (s) - Frequency of changes in gaze location (changes/min) - Percentage of time looking toward a location Questionnaire	Simulator-based experiments	Participants spent more time looking toward the patient and less time toward the anesthesia machine, and were faster at detecting patient abnormal changes, when they wore the HMD than when they used standard monitoring alone. When using the HMD, participants reported that they were less busy, monitoring was easier, and they believed they were faster at detecting abnormal changes.	A simulated operating theater environment in a hospital	12 anesthesiologists
Lu, J., & Hignett, S. (2009). Using task analysis in healthcare design to improve clinical efficiency. <i>Health Environments Research and Design Journal</i> , 2 (2), 60-69.	Soiled workroom design	Spatial layout of soiled workroom (location of equipments on floor plans)	Work efficiency	Link analysis was used to record and analyze the movements among components, i.e., nursing staff, equipment/devices, and furniture. - Tasks occupied the most space; - Area had the highest level of activity (to determine the layout and adjacency requirements of equipment and furniture); - Area needed the easiest access.	Concurrent comparison, cross sectional	The most frequent tasks were the disposal of urine and used urine bottles, and returning used commode chairs. The hand-wash basin and yellow-bag bin were the most intensively used items for all tasks.	Five clinical departments at three hospitals in U.K.	54 observations for 18 clinical tasks
Miskovic, D., Rosenthal, R., Zingg, U., Oertli, D., Metzger, U., & Jancke, L. (2008). Randomized controlled trial investigating the effect of music on the virtual reality laparoscopic learning performance of novice surgeons. <i>Surgical Endoscopy</i> , 22 (11), 2416-2420.	Music	Three conditions: activating (arousing) music (e.g. Richard Wagner's "Valkyrie"), deactivating music (e.g. Nicholas Gunn's "Seeking Serenity"), no music. Music played on a computer with a constant volume of 35 dB. Participants evaluated the musical pieces on a visual analog scale relating to the subjectively experienced emotional valence (pleasant vs. unpleasant).	Surgeon performance on a laparoscopy task	LS500 (Xitact) virtual patient laparoscopy simulator, run by a Pentium PC with a high-resolution thin film transistor (TFT) monitor connected to two robotic force feedback devices acting as interfaces for the laparoscopic instruments. - Global task score (the anatomy scores [accuracy of cystic duct and artery clipping] minus the error score [e.g., clipping errors, cutting errors, bleeding], with a minimum score of 0) - The total task time - The instrument travel distances - The surgeon's heart rate	Experiment with repeated measurements in five trials	Surgeons' efficiency and performance improved over time (total task time decreased, global task score increased). Surgeons who listened to activating music performed worse than the other two groups in the first trial but not in the subsequent trials. Surgeons who rated the music as pleasant solved the task quicker than surgeons who rated music as unpleasant and no music.	Simulated operating theatre.	45 junior surgeons with no previous laparoscopic experience

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Moorthy, K., Munz, Y., Dosis, A., Bann, S., & Darzi, A. (2003). The effect of stress-inducing conditions on the performance of a laparoscopic task. <i>Surgical Endoscopy</i>, 17(9), 1481-1484.	Noise	Five experimental conditions: operating theatre background noise at 80 to 85 dB (N), a simple verbal mathematical task (M), performance as quickly as possible (T), all three stressors combined (A), and quiet conditions (Q).	Surgical performance on a laparoscopy task	The surgical task was to move cylindrical pieces of sponge from one disc to another. Surgical performance was measured by the Imperial College Surgical Assessment Device. When motion tracking sensors attached to the dorsum of both hands move in an electromagnetic field generated by the system, the positional data from the trackers gets converted into data on the number of movements and the path length traversed by each hand using specially developed software.	Experiment with repeated measurements in 5 conditions	All three stressors led to impaired dexterity and an increase in the incidence of errors. There were increases in path length per movement of the right hand and the left hand (insignificant trends in noise conditions and significant in all other conditions). There were more errors in all conditions.	Simulated operating theatre	13 right-handed surgeons with varying levels of laparoscopic experience
O'Connor, C., Friedrich, J. O., Scales, D. C., & Adhikari, N. K. (2009). The use of wireless e-mail to improve healthcare team communication. <i>Journal of the American Medical Informatics Association</i>, 16(5), 705-713	Wireless communication in a ICU with two separated unit areas	Wireless e-mail over a GSM cellular network using handheld devices (BlackBerry, Research in Motion, Waterloo, ON). Baseline: receive-only numeric pagers, overhead paging, physical searches for staff, handwritten messages left in or near patient charts, and e-mail accessed by computers	Staff communication, teamwork, satisfaction	Questionnaire, 49 items, developed by interview, focus group, pretesting. - Perceived impact of wireless e-mail on communication, team relationships, staff satisfaction and patient care. Items included: improved speed of communication, improved reliability of communication, less effort required to communicate, improved physician response times to critical issues, etc. 7 point scale.	POE	Staff reported that wireless e-mail improved speed (92%) and reliability (92%) of communication, improved coordination of ICU team members (88%), reduced staff frustration (75%), and resulted in faster (90%) and safer (75%) patient care.	A 26-bed ICU in a community hospital in Canada	ICU staff (intensivists, nurses, respiratory therapists, pharmacists, clerical staff, and ICU leadership)
Ortega, G. R., Taksali, S., Smart, R., & Baumgaertner, M. R. (2009). Direct cellular vs. indirect pager communication during orthopaedic surgical procedures: a prospective study. <i>Technology and Health Care</i>, 17(2), 149-157.	Communication system	Direct cellular communication (answered by surgeon using wireless ear piece) vs. indirect page communication (answered by the OR circulating nurse for communication between the surgeon, circulating nurse, and floor nurse)	Nurse to surgeon communication when the surgeon was scrubbed in the operating room (OR) without breaking sterile technique; Surgeon to nurse communication study occurred while the nurse was actively involved with patient care	Direct observation, stop-watch - Response rate - Correct patient ID time (time between nurse's presentation of the patient's name to confirmation by the surgeon to be the caregiver) - Error rate (communication changes in the preestablished question or answer) - Response time (the time from first phone call ring to answer by the surgeon directly or indirectly) - Solution time (the time from nurse's question to the surgeon's solution presentation) - Communication time (time from first phone call ring to the end of the communication) - Floor nurse satisfaction (excellent--no delay in response < 5 minutes and no difficulties; acceptable--delay between 5-10 minutes and/or non-hindering difficulty; unacceptable - delay > 10 minutes and/or a hindering difficulty) - Intraoperative case interruptions (the surgeon had to leave the attention of the surgical field by either discontinuing the procedure and/or having to leave the operating table)	Concurrent comparisons	Direct cellular communication showed a better response rate than indirect page (Cell 100%, Page 73%). Direct cellular communication significantly reduced errors in communication. Cellular communication showed statistically significant improvements in mean time intervals in response time (Cell = 11s, Page = 211s), correct patient identification (Cell = 5s, Page = 172s), patient problem and solution time (Cell = 13s, Page = 189s), and total communication time (Cell = 32s, Page = 250s). Floor nurse satisfaction ratings were higher with cellular communication. Intraoperative case interruptions were more frequent with indirect page communication.	The OR and orthopaedic floor in a hospital	60 trials: 30 cell and 30 page communications

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Pati, D., Cason, C., Harvey, T. E., Jr., & Evans, J. (2010). An empirical examination of patient room handedness in acute medical-surgical settings. <i>Health Environments Research and Design Journal</i> , 4 (1), 11-33.	Patient room layout	Nine physical design configurations determined by two factors: - Direction of approach to the patient (right-handed, left-handed, and neutral-handed configurations) - The presence or absence and location of an intravenous (IV) line to the patient, using a mobile pole (IV pole on patient's left, on patient's right, and no IV pole)	Nursing behavior when performing three tasks: checking vital signs, suctioning the patient, sitting the patient up. Nurse perceptions	- Videotaping recorded by ceiling-mounted cameras and processed by custom-made software installed on computers. Activities: direction of approach, any hesitation in approach, over-bed table use, bed rail adjustment, bed height adjustment, and bed angle adjustment. The number of times the following postures were observed: stretch, bend, unstable, lift, twist, and reposition. - Interview questions focused on (a) workflow, (b) perceived awkward postures or movement, (c) elements of the settings perceived as supportive of the tasks conducted, and (d) factors influencing the approach decision.	Simulation-based quasi-experimental design	Within group analysis (two groups: left-handed, right-handed) showed that there was minimal variations between the nine conditions over the three tasks. Left-handed and right-handed nurses differ significantly in many behaviors when conducting the three tasks in the study. Multiple factors affecting a nurse's position vis-à-vis the patient. Most of the respondents identified the set of layouts without partition as the one that best supported their tasks. The open configuration provided an immediate global view of the condition of the caregiver zone and the equipment layout.	A simulated acute medical-surgical unit setting in a simulation training laboratory at the college of nursing of a large university	20 nursing students and faculty (10 right-handed, 10 left-handed)
Poley, M. J., Bouwmans, C. A., Hanff, L. M., Roos, P. J., & van Ineveld, B. M. (2004). Efficiency of different systems for medication distribution in an academic children's hospital in The Netherlands. <i>Pharmacy World & Science</i> , 26 (2), 83-89.	Medication distribution system; Computerization of the medication order registration	- A decentralized, patient-orientated, ready-to-use drug distribution system (a 'satellite pharmacy system') including satellite pharmacies close to the wards. A ward stock system. Routinely used drugs are issued by the hospital's central pharmacy, which is located in a neighboring building, and stored in cupboards on the wards. - An on-line computerized physician order-entry system	Workload of the two current distribution systems	Direct time study. Direct observation of time that nurses, physicians, and pharmacy technicians spent on all activities of the distribution process, from prescription up to administration of the drug. 2 activity categories: prescription and administrative activities; preparation and dispensing of drugs. 12 drug categories.	Concurrent comparisons between nursing units using different medication distributions systems	Nurses had a higher share of drug preparing and dispensing in satellite system. Registering drug orders was time consuming. An on-line computerized physician order-entry system could save 40% of time of pharmacy technicians and nurses. working hours would be reduced if complex medications and preparation of drugs are moved to technicians in the satellite pharmacies.	A academic children's hospital in Netherlands	All medication orders and prepared doses were counted over a three-month period in the selected units
Sanderson, P. M., Tosh, N., Philp, S., Rudie, J., Watson, M. O., & Russell, W. J. (2005). The effects of ambient music on simulated anesthesia monitoring. <i>Anesthesia</i> , 60 (11), 1073-1078.	Music	Rock music (tracks from the Bryan Adams albums 'Cuts like a knife' and 'Waking up the neighbors') Classical music (J. S. Bach violin concertos and sinfonias in D minor) No music	Anesthesia monitoring performance	- During simulated monitoring of visual and auditory displays of patients' vital signs (nine anesthesia test scenarios), participants were asked every 50-70 s whether one of five vital signs was abnormal (abnormality judgments: normal, high, low) and the trend of its direction (trend judgments: steady, increasing, decreasing, fluctuating), anesthesia simulator (Advanced Simulation Corporation's Body TM physiological and pharmacological engine, connected to an interface largely similar to the Body TM Anesthesia Simulator interface). Percentage of correct judgments. - Questionnaire (ease of monitoring) on 7-point scale	Experiment	Abnormality judgments were unaffected by music or musical training. Trend judgments were more accurate when music was playing. However, participants reported that it was easier to monitor the patient with no music and to rely upon the auditory displays with no music	A hospital in Australia	24 non-anesthetist participants with high or low levels of musical training

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Shepley, M. M. (2002). <i>Pre-design and postoccupancy analysis of staff behavior in a neonatal intensive care unit. Children's Health Care, 31 (3), 237-253.</i>	NICU design	Old NICU: six rooms for 1-5 beds each New remodeled NICU: open unit with 60% more area than the old unit, more storage spaces in patient areas, additional amenities including an alcove where mothers could be trained to breast-feed, a sleep room equipped with medical gas outlets where parents could be taught to care for their ill babies	Staff activity	Behavioral mapping - Activity (20 types), location (31), and time data, nurse type were recorded sequentially - Pedometer Interview Questionnaire - 60 items, focusing on the efficiency of the floor plan, perceptions of space allocation, and the impact of natural light	Before-after study	The ratio of nurse time in traveling to the total unit area significantly decreased in the new unit. Insignificant trends showed that staff spent more time with infants and families in the new unit. The number of transactions with families increased significantly. Time on a single supply transaction decreased significantly. Staff reported that decentralized storage was a good idea in theory but there was not enough time to keep the substations stocked. Most staff thought that the open floor plan was an efficient design solution.	A NICU Level III nursery in a large, urban public hospital in California	124 hr of observation 39 participant cases 10 nurses
Shepley, M. M., & Davies, K. (2003). <i>Nursing Unit Configuration and Its Relationship to Noise and Nurse Walking Behavior: An AIDS/HIV Unit Case Study. AIA Academy Journal, Retrieved May 2, 2011 from http://aiawebdev2.aia.org/aah2_template.cfm?pagename=aah_a_jrnl_0401_article4</i>	Nursing unit layout design	Dense radial configuration (circular configuration with patient rooms radiating around the circumference and nurse station at the center, 10 beds, 8,100 SF, 2 nurses, carpeted, with low-volume radio) - Double corridor rectangular (nurse station/support space in the core, patient rooms on the perimeter wall, 24 beds, 18,500 SF, 5-10 nurses, resilient flooring)	Walking distance Noise	- Steps per minute (electronic pedometer attached to back of staff's belts) - Noise level (noise-logging dosimeter with an operating range of 30-125 dB, average noise level in 5-minute intervals for 6 or 7 days)	Concurrent comparison	Nurses in the radial unit walked an average of 4.7 steps per minute; nurse in the rectangular unit took 7.9 steps per minute (p <0.01). Noise levels in the two units were comparable (averaged 60-61 dB)	Two nursing units managed by same health organization focusing on HIV/AIDS patients	174 hr of noise recording in the rectangular unit and 140 hr in the radial unit Nurses in the two units
Trites, D. K., Galbraith, F. D., Sturdavant, M., & Leckwart, J. F. (1970). <i>Influence of nursing-unit design on the activities and subjective feelings of nursing personnel. Environment & Behavior, 2 (3), 303-334.</i>	Nursing unit layout design	12 units, three types of layout, four units in each type: radial, single-corridor rectangular, double-corridor rectangular (similar size in number of beds, different service lines, higher percentages of single rooms in single-corridor units than double-corridor units and radial units)	Staff behavior Staff perception	Observation. - Observers made rounding of the facility at specific time points and recorded activities. Staff activities classified in 9 categories (e.g. direct patient care, indirect patient care, nonproductive time), locations in 5 categories (e.g. nurse station, patient room), other two categories (with patient, total not travel) Questionnaire - Surveys before and after every shift (e.g. tension, anxiety, psychosomatic disturbances, fatigue, perceptions of work efficiency and work load)	Concurrent comparison	Staff in radial unit spent significantly more time with patients and less time in travel than staff in single- and double-corridor units. Staff in radial units tended to be found more often in the nurse station and to have nonproductive time in day and night shifts. Most nursing staff preferred to work in radial units and thought the design improved the quality of patient care.	12 nursing units in a new facility in a big hospital	590 different staff members
Wietholter, J., Sitterson, S., & Allison, S. (2009). <i>Effects of computerized prescriber order entry on pharmacy order-processing time. American Journal of Health-System Pharmacy, 66(15), 1394-1398.</i>	Computerized prescriber order entry system	Before and after implementation of CPOE which eliminated the step of pharmacist data entry	Medication processing time	Review of medication records - The time the prescriber ordered the medication, the time the pharmacy received the order, and the time the order was completed by a pharmacist	Before-after study	The mean order-processing time was reduced from 115 minutes before implementation to 3 minutes after CPOE implementation. The time that an order was received by the pharmacy to the time it was verified by a pharmacist was reduced from 31 minutes to 3 minutes.	A 761-bed, tertiary care hospital in NC	1488 medication orders before and 1500 after CPOE implementation

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Zborowsky, T., Bunker-Helmich, L., Morelli, A., & O'Neill, M. (2010). Centralized vs. decentralized nursing stations: Effects on nurses' functional use of space and work environment. <i>Health Environments Research and Design Journal</i> , 3(4), 19-42.	Nurse station layout design	Centralized nursing station vs. decentralized nursing station--Two units in each of the three hospitals: one with centralized nursing station design and the other with a decentralized nursing station design	Nurse activity Nurse perceptions	<p>Observation of place- and person-centered space use.</p> <ul style="list-style-type: none"> - Frequency and duration of activities recorded by a digital timer and visual data charts. - Visibility (the number of patient beds and patient rooms in direct view of the nursing station and the number of monitors used in the nursing station). <p>Sound levels--portable decibel meter (Extech Model #407738)</p> <p>Focus group interviews, 7 questions focusing on how nursing unit design might affect the overall health, perceived professional status, quality of patient care, professional work needs, communication, multitasking, workflow, and efficiency of nursing staff.</p> <p>On-line questionnaire, 35 questions assessing nurses' experienced workplace demand, control, and support based on Karasek and Theorell's (1990) Demand-Control-Support instrument</p>	Concurrent comparison	Activities nurses most frequently engaged in included telephone, computer, and administrative duties. Nurses in centralized stations spent more time using telephones, computers, and performing other administrative duties. Nurses in decentralized stations less frequently engaged in consultations with medical staff and social interactions.	Six nursing units located in three U.S. hospitals	Ten 20-minute observation periods for each unit for place-centered observation; 3 nurses in each unit for person-centered observation; 13 nurse in two focus groups; 57 questionnaire respondents

Matrix of relationships

		Outcome				
	Variable	Staff travel	Team communication	Circadian misalignment	Medication processing time	Surgeon/anesthesiologist performance
Environmental feature	Nurse station layout					
	Nursing unit shape/layout					
	Noise					
	Music					
	Illumination level					
	Patient room occupancy					
	Patient room layout					
	Workroom layout					
	Medication distribution system					
	Pharmacy equipment					
	Head mounted display					
Wireless technology						

 Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

Staff Satisfaction: Glossary (variables, metrics and measurement methods)

	Term	Definition	Metrics	Measurement method
Environmental variable	Acuity-adaptable room (single room maternity care)	Single-room maternity care refers to maternity care rooms where families are admitted and stay throughout the intrapartum and postpartum periods. The rooms are spacious and include amenities for families. They differ from the traditional care model which requires patients to transfer between multiple rooms, depending upon their care status (Janssen et al., 2001).	- Yes/no, before/after (Janssen et al., 2001)	Design manipulation - Survey responses from a same group of nurses were collected 6 months before and 3 months after moving from a traditional unit to a single-room maternity care unit (Janssen et al., 2001).
	Attractiveness, physical environment	Aesthetic appeal of the physical environment, including the surrounding external environment, the architectural design, facility upkeep and cleanliness, and other physical elements (Becker & Douglass, 2008)	- Two types of design: an old cement building (transferred from a juvenile hall, ugly and depressing, dimly lighted, glare, stuffy, noisy) versus a new facility (pleasant-looking wood-paneled cottages where staff felt freer, lighter, and more positive; well lighted, adequate ventilation, quiet) (Folkins, O'Reilly, Roberts, & Miller, 1977)	Design manipulation - Pleasant-looking wood-paneled cottages where staff felt freer, lighter, and more positive; well lighted, adequate ventilation, quiet (Folkins et al., 1977).
	Daylight	Light originating from the sun that reaches Earth's surface after reflecting off the sky's vault (Zunde & Bougdah, 2006)	- Hours of exposure to direct daylight in a typical work day (less than 3h versus 3h or more) (Alimoglu & Donmez, 2005)	Questionnaire survey - Self-reported by a question asking about length of exposure in a personal data collection form (Alimoglu & Donmez, 2005).
	Noise	A sound that is loud, unpleasant, unexpected, or undesired (Free Dictionary)	- Equivalent sound pressure level (LAeq) (weighted average sound pressure level in dBA), minimum and maximum sound level, auditory events (alarm, telephone, etc.) (Morrison et al., 2003) - Perception of noise (Applebaum et al., 2010).	Acoustic measurement - Sound pressure levels recorded continuously by a Quest Advanced 1900 precision integrating logging sound level meter (Morrison et al., 2003) Questionnaire survey - Items about perceived noise in M. D. Anderson Patient Contact Survey (Applebaum et al., 2010).

	Term	Definition	Metrics	Measurement method
	Patient room occupancy	The number of patients per patient room—one per room (single room, private room), two (double room), four-bed room, multi-bed open bays (Shepley, Harris, & White, 2008).	Single family room versus open bay (Shepley, Harris, & White, 2008).	Design manipulation - Comparison between three types of patient spaces: single rooms from an all-single-room NICU, single rooms and open bays from another NICU (Shepley, Harris, & White, 2008)
Outcome	Burnout	A prolonged psychological response to chronic emotional and interpersonal stressors on the job and defined by three dimensions –emotional exhaustion (EE), depersonalization (D), and low personal accomplishment (PA). EE refers to feelings of being overextended and depleted of emotional and physical resources. D refers to a negative, callous, or excessively detached response to various aspects of the job. PA refers to feelings of incompetence and a lack of achievement and productivity at work (Alimoglu & Donmez, 2005).	Self-reported burnout scores (Alimoglu & Donmez, 2005)	Questionnaire survey - Maslach Burnout Inventory (22 items in 3 subscales 'emotional exhaustion', 'depersonalization', 'personal accomplishment', 5-point scale 0 never to 4 always, [Maslach & Jackson, 1996], Turkey translation [Ergin, 1992] (Alimoglu & Donmez, 2005; Tyson et al., 2002)

	Term	Definition	Metrics	Measurement method
	Job satisfaction	A pleasurable or positive emotional state in an individual, resulting from the appraisal of that person's job or job experiences (Berry & Parish, 2008).	Self-reported job satisfaction scores (Alimoglu & Donmez, 2005; Applebaum et al., 2010; Berry & Parish, 2008; Djukic et al., 2010; Folkins et al., 1977; Harris et al, 2006; Jason, et al., 2002; Shepley et al, 2008; Tyson et al., 2002; Varni et al., 2004)	<p>Questionnaire survey</p> <ul style="list-style-type: none"> - Job Satisfaction Scale (JSS), a 5-item subscale from the Nurse Stress Index by Harris, Hingley, and Cooper (1988) (Harris et al., 2006; Shepley et al., 2008) - Work Satisfaction Questionnaire (14 items, 5-point scale from 1 never satisfies me to 5 highly satisfies me, [Hackman & Oldham, 1980] (Alimoglu & Donmez, 2005) - One item in a staff questionnaire (Berry & Parish, 2008) - Nurses' Intent to Stay Questionnaire (NISQ) (Job satisfaction 7 items, turnover intent 4 items (Applebaum et al., 2010) - A five-item Likert type job satisfaction scale with response category varying among items and rescaled to a 7-point scale (Djukic et al., 2010) - Minnesota Satisfaction Questionnaire (Weiss, Dawis, England, & Lofquist, 1967) - GM Faces Scale (Kunin, 1955), a simple, well-validated measure including seven drawings of faces with facial expressions ranging from a frown to a smile (Folkins et al., 1977) - Rehabilitation Job Satisfaction Inventory (Wright & Terrian, 1987) including 15 items, agreement with the statement on a 5-point scale, the final score of job satisfaction was calculated from 4 items (satisfied with job, plan on staying, the best compared to past jobs, look forward to going to work) (Jason et al., 2002) - Job Satisfaction (Warr et al., 1979), satisfaction with extrinsic and intrinsic features of the job as well as overall job satisfaction, 16 items (Tyson et al., 2002) - PedQL Staff Satisfaction Coworker Module (Varni et al., 2004)
	Perception of physical environment	Quality of the physical environment as perceived by healthcare staff members. May include perceptions of environmental aspects such as quality of the patient care area (comfort and privacy afforded to patients and families due to the design of patient areas), safety (degree of hazard for staff and patients related to facility design), pleasantness (ambience of the facility design due to specific design features) (Berry & Parish, 2008).	Subjective rating of physical environment (Berry & Parish, 2008; Harris et al, 2006; Shepley et al, 2008)	<p>Questionnaire survey</p> <ul style="list-style-type: none"> - Perception of physical environment (quality of patient areas [4 items], safety [3 items], pleasantness [3 items], quality of workspace [6 items]) (Berry & Parish, 2008) - Level of agreement with statement regarding the physical environment, 12 questions, 5-point scale, average score (e.g., quiet, private space for family to be alone, atmosphere tense and stressful for staff/family) (Harris et al, 2006; Shepley et al, 2008)

	Term	Definition	Metrics	Measurement method
	Stress, staff	A state of mental or bodily tension caused by the imbalance between an individual's environmental demands or perceived demands and the individual's ability or perceived ability to cope with the environmental demands (Stokols & Montero, 2002).	<p>Physiology measures</p> <ul style="list-style-type: none"> - Heart rate (average HR [bpm], minimum, maximum HR for every half-hour period, percent of time in tachycardia [HR>100], number of episodes of ectopy [disturbance of the cardiac rhythm]) (Morrison et al., 2003) - Salivary amylase concentration (units per mL) (Morrison et al., 2003) <p>Psychology measures</p> <ul style="list-style-type: none"> - Self-reported stress and annoyance (Alimoglu & Donmez, 2005; Morrison et al., 2003) 	<p>Electrocardiography (ECG) monitoring</p> <ul style="list-style-type: none"> - A portable cassette battery-driven Holter monitor (GE Marquette 8500 series, Milwaukee, WI) (Morrison et al., 2003) - Salivary hormone analysis - A citric acid impregnated cellulose sponge, salivary amylase field test kits (Morrison et al., 2003). <p>Questionnaire survey</p> <ul style="list-style-type: none"> - Expanded Nurse Stress Scale (ENSS) by French, Lenton, Walters, and Eyles (2000), 59 items in 9 subscales (Harris et al., 2006; Shepley et al., 2008). - Specific Rating of Events Scale, nurses rated how stressed or annoyed "right now" on a scale of 0 for "not at all stressful" or "not at all annoyed" to 100 for "most stress possible" or "most annoyance possible" (Morrison et al., 2003) - Work Related Starin Inventory (18 items about work-related expectations, stress, interpersonal relations, productivity, working habits, interactions between work and family [Revicki et al., 1991], 4 point scale from 1 surely agree to 4 surely disagree (Alimoglu & Donmez, 2005) - 3 items in a questionnaire developed specifically for the study (Berry & Parish, 2008)
	Turnover intent	Employees' inclination to voluntarily leave their organization (Haybatollahi, 2009).	Self-reported turnover intent (Applebaum et al., 2010; Lin et al., 2008)	<p>Questionnaire survey</p> <ul style="list-style-type: none"> - Nurses' Intent to Stay Questionnaire (NISQ) (turnover intent 4 items) (Applebaum et al., 2010) - Variables measured on a 0-100 scale (Lin et al., 2008).

Staff Satisfaction: Article Analysis

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Alimoglu, M. K., & Donmez, L. (2005). Daylight exposure and the other predictors of burnout among nurses in a University Hospital. <i>International Journal of Nursing Studies</i> , 42(5), 549-555.	Exposure to daylight	Hours of exposure to direct daylight in a typical work day (less than 3 h vs. 3h or more) self-reported by a question asking about length of exposure collected together with demographic, socio-economic, personal and work-related issues in a personal data collection form.	Burnout Stress Job satisfaction	- Maslach Burnout Inventory (22 items in 3 subscales 'emotional exhaustion', 'depersonalization', 'personal accomplishment', 5-point scale 0 never to 4 always, [Maslach & Jackson, 1996], Turkey translation [Ergin, 1992], Cronbach alpha 0.89, 0.71, 0.72 for subscales) - Work Related Strain Inventory (18 items about work-related expectations, stress, interpersonal relations, productivity, working habits, interactions between work and family [Revicki et al., 1991], 4 point scale from 1 surely agree to 4 surely disagree, Cronbach alpha 0.74) - Work Satisfaction Questionnaire (14 items, 5-point scale from 1 never satisfies me to 5 highly satisfies me, [Hackman & Oldham, 1980], Cronbach alpha 0.82)	Correlation study	Longer exposure of natural daylight was associated with lower level of stress and higher level of job satisfaction, but was not related to the three subscales of burnout. Other factors contributing to stress included: suffering from sleep disorders and having night duties. Other factors associated with job satisfaction were: suffering from sleep disorders, working in inpatient services, and satisfaction with wages. Job satisfaction was negatively associated with emotional exhaustion and depersonalization, and positively related to personal accomplishment.	A university hospital in Turkey	141 nurses
Applebaum, D., Fowler, S., Fiedler, N., Osinubi, O., & Robson, M. (2010). The impact of environmental factors on nursing stress, job satisfaction, and turnover intention. <i>Journal of Nursing Administration</i> , 40(7-8), 323-328.	Perception of environmental elements (odor, color, light, noise)	- M. D. Anderson Patient Contact Survey (15 items for environmental factors (limited testing on validity and reliability, Cronbach alpha 0.7-0.8)	- Staff stress - Job satisfaction - Turnover intent	- 10-item Perceived Stress Scale (PSS-10) (all 10 items, validated) - Nurses' Intent to Stay Questionnaire (NISQ) (Job satisfaction 7 items, turnover intent 4 items, validated)	Correlation study	Significant relationships were found between perceived noise and stress, between stress and job satisfaction, between stress and turnover intent, and between job satisfaction and turnover intent.	Adult medical-surgical units at a 500-bed level I trauma center in northeastern NJ	116 full-time RNs
Berry, L. L., & Parish, J. T. (2008). The impact of facility improvements on hospital nurses. <i>Health Environments Research and Design Journal</i> , 1(2), 5-13.	Patient unit design	New units (all single rooms that are 20% to 50% larger than old rooms, with more natural light, more handwashing stations, and staff break rooms) vs. old units	- Nurse perception of physical environment - Job stress - Job satisfaction - Perceived service quality	Questionnaire - Perception of physical environment (quality of patient areas [4 items], safety [3 items], pleasantness [3 items], quality of workspace [6 items]) - Job stress (3 items) - Job satisfaction (1 item) - Perceived service quality (5 items)	Before-after comparison (6 month before and 6 month after the move)	Nurses working in the new building rated the physical environment more positively, reported higher job satisfaction, lower stress, and higher perceived quality of care than nurses staying in the old building and the pre-move sample.	A 210-bed community hospital in TX	Pre-move: 235 registered and licensed nurses , Post-move: 173 nurses stayed in the old building, 65 nurses moved to the new building
Cannon, G. W., Keitz, S. A., Holland, G. J., Chang, B. K., Byrne, J. M., Tomolo, A., . . . Kashner T.M. (2008). Factors determining medical students' and residents' satisfaction during VA-based training: Findings from the VA Learners' Perceptions Survey. <i>Academic Medicine</i> , 83(6), 611-620.	Perceptions of physical environment	12 items on 5-point scale: - Facility maintenance upkeep - Facility cleanliness/housekeeping - Call rooms - Availability of food at medical center when on call - Heating and air conditioning - Lighting - Availability of needed equipment - Maintenance of equipment - Convenience of facility location - Personal safety - Parking - Availability of phones	Overall satisfaction Other factors impacting satisfaction (learning environment, clinical faculty, working environment)	- Overall training satisfaction on a 100-point scale (1 item) - Learning environment (15 items) - Clinical faculty (13 items) - Working environment (13 items)	Correlational study	Physical environment factors (including facility maintenance/upkeep, facility cleanliness/housekeeping, call rooms, availability of food on call, availability of equipment) were significantly correlated with the overall satisfaction	VA teaching facilities	6,527 medical students and 16,583 physician residents

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
<p>Cleary, M., Hunt, G., & Walter, G. (2009). A comparison of patient and staff satisfaction with services after relocating to a new purpose-built mental health facility. <i>Australasian Psychiatry</i>, 17 (3), 212-217.</p>	<p>A new purpose-built mental health facility</p>	<p>New purpose-built mental health facility, 174 beds, a setting complementary to the therapeutic process, patients stay in private rooms within single story units and are allocated to wards based on their phase of illness and treatment requirements, smoke-free environment (vs. the old site).</p>	<p>Staff satisfaction Patient satisfaction</p>	<p>Survey with staff, interview with patients - Inpatient Evaluation of Services Questionnaire (5 dimensions: patient characteristics, service dimensions [22 items in 9 subscales: ward environment, food services, outcome, overall satisfaction, nursing services, staff/patient interaction, allied health services, doctor/medical services, patient information], patient expectations of treatment, patient intent to use services again, suggestions on improving the service; 5-point scale) Additional questions included general questions about the new facility and aspects at the new workplace.</p>	<p>Descriptive, POE</p>	<p>Staff and patients were highly satisfied with the new ward environment and food services but less satisfied with patient information and medical services. Most staff reported that services provided to patients were the same or better than their original expectations.</p>	<p>A new purpose-built mental health facility within the grounds of a general repatriation hospital in Australia.</p>	<p>123 clinical nursing, medical and allied health staff; 100 patients</p>
<p>Djukic, M., Kovner, C., Budin, W. C., & Norman, R. (2010). Physical work environment: testing an expanded model of job satisfaction in a sample of registered nurses. <i>Nursing Research</i>, 59 (6), 441-451.</p>	<p>Physical work environment</p>	<p>Physical comfort subscale of the Work Environment Scale (WES), 9 items - one architectural feature (workspace size), 4 interior design features (e.g. furniture is usually well arranged), 4 ambient features (e.g. temperature, lighting, air flow), two point scale (yes/no), number of "yes" responses (0-9)</p>	<p>Job satisfaction</p>	<p>A five-item Likert type job satisfaction scale with response category varying among items and rescaled to a 7-point scale. (Quinn & Staines, 1979).</p>	<p>Correlation study</p>	<p>RN's had negative perception of physical work environment. Perception of physical environment was positively related to job satisfaction in bivariate analysis.</p>	<p>A large urban hospital in US with 32 inpatient units</p>	<p>362 RN's</p>
<p>Folkins, C., O'Reilly, C., 3rd, Roberts, K., & Miller, S. (1977). Physical environment and job satisfaction in a community mental health center. <i>Community Mental Health Journal</i>, 13 (1), 24-30.</p>	<p>Building aesthetics</p>	<p>Old mental health facility (a cement building transferred from a juvenile hall, ugly and depressing, dimly lighted, glare, stuffy, noisy) New mental health facility (pleasant-looking wood-paneled cottages where staff felt freer, lighter, and more positive; well lighted, adequate ventilation, quiet)</p>	<p>Staff satisfaction with physical environment Job satisfaction</p>	<p>Minnesota Satisfaction Questionnaire (Weiss, Dawis, England, & Lofquist, 1967) GM Faces Scale (Kunin, 1955), a simple, well-validated measure including seven drawings of faces with facial expressions ranging from a frown to a smile.</p>	<p>Quasi-experimental, control series, repeated measurements in three time points: 12 months, 2 months before move, and 4 months after the move</p>	<p>Staff members has significantly higher satisfaction with physical environment after they moved to the new facility. Staff who stayed in the old facility had similar environmental satisfaction ratings in all three time points. Satisfaction with physical environment influenced the overall job satisfaction.</p>	<p>A community mental health center</p>	<p>Three teams of staff, two (8, 13 staff members) moved to the new facilities, one (14 staff members) stayed in the old facility)</p>

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
<p>Harris, D., Shepley, M. M., & White, R. (2006). <i>The impact of single family NICU rooms</i>. San Francisco, CA: Coalition for Health Environments Research.</p> <p>Shepley, M.M., Harris, D.D., & White, R.D. (2008). Open-bay and single-family room neonatal intensive care units. <i>Environment & Behavior</i>, 40 (2), 249-268.</p>	Patient room occupancy type	Single family room vs. open bay (single rooms from a all single room NICU, single rooms and open bays from another NICU)	Staff satisfaction with the physical environment; Staff perception of the physical environment; Staff perceived stress; Job satisfaction.	<ul style="list-style-type: none"> - Degree of satisfaction with the physical environment, 10 questions, 5-point scale, average score (overall physical environment, windows views, natural light, light level, noise level, atmosphere and decor, waiting and resting space, corridors and signage for wayfinding, place for food and nourishment) - Level of agreement with statement regarding the physical environment, 12 questions, 5-point scale, average score (e.g. quiet, private space for family to be alone, atmosphere tense and stressful for staff/family) - Expanded Nurse Stress Scale (ENSS) by French, Lenton, Walters, and Eyles (2000), 59 items in 9 subscales, scoring by summation of items - Job Satisfaction Scale (JSS), a 5-item subscale from the Nurse Stress Index by Harris, Hingley, and Cooper (1988), scoring by summation of items 	Comparison between three types of patient spaces in two units	Staff in the all single room unit were more satisfied with the physical environment than staff in the unit with a combination of single rooms and open bays. Single rooms were perceived to be superior in providing privacy to families and infants and to be less stressful for both family and staff members. Both groups of staff in single rooms reported lower stress level and higher job satisfaction level than the group with the open bays.	Two level III NICUs in US	75 respondents (21 from the all single room NICU, 27 and 21 respectively from open bays and single rooms in another NICU)
<p>Janssen, P. A., Harris, S. J., Soolsma, J., Klein, M. C., & Seymour, L. C. (2001). Single room maternity care: The nursing response. <i>Birth</i>, 28 (3), 173-179.</p>	Maternity care patient room	<ul style="list-style-type: none"> - Single room maternity care unit in which patients stay in one room throughout the intra- and post-partum periods, large enough for staff and family, sofa for the support person to sleep on, windows, modern fabrics maple furniture, bathrooms with showers/bathtubs - Delivery suite, smaller rooms, no windows, one chair, a shower - Postpartum ward, small rooms, with showers, bathtubs, windows, patios, 14% of rooms are shared. 	Job satisfaction	<ul style="list-style-type: none"> - Survey based on literature review, staff feedbacks, and tools developed at other hospitals, divided into several sections: <ul style="list-style-type: none"> - perception of physical setting (room spacious, setup similar, lights adequate, supplies accessible, resuscitation equipment available, privacy easily maintained, noise acceptable, water therapy choices easily accommodated, family centered care), - quality of care (opportunity to teach partners, respond to needs of physical, emotional, and spiritual care, teach family, comfortable with family making choices, overall quality of care, continuity of care), - perceived competence and nursing practice environment (autonomous nursing decisions, accountable for decisions, promotes clinical competence, opportunity for collaboration and teamwork, staffing ratio sufficient, support and assistance for nursing decisions, medical staff readily available, feel competent caring for family, areas in which not competent, overall job satisfaction). - Items were scored on scale of 1-5, statistical analyses on individual items 	Before-after, repeated measurements (comparison of survey responses from same group of nurses 6 months before and 3 months after the move to single room unit), concurrent comparisons (comparisons between the above group after move with other two groups in multi-bed units)	The nurses in single room maternity care were significantly more satisfied than nurses in traditional delivery and postpartum settings. Their satisfaction significantly increased after the move to single room maternity care in the following areas: the physical environment, their ability to respond to patients' needs, their opportunity for teaching families, nursing practice environment, peer support, perceived competence.	Maternity care units in an obstetric hospital in Canada	20 nurses in the single room maternity care, 26 nurses in the delivery suite, 26 nurses in the postpartum ward


Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Jason, D. A., Clayton, W. F., & Charles, D. P. (2002). The relationship between counselor satisfaction and extrinsic job factors in state rehabilitation agencies. <i>Rehabilitation Counseling Bulletin, 45</i> (4), 223.	Satisfaction with physical environmental factors	Self-developed survey instrument--Environment of Job Satisfaction Survey, 20 items, agreement with the statement on a 5-point scale, importance rating on a 3-point scale. Items include: conveniently located for access us, conveniently located to access rehabilitation resources, in a geographic area suited to me, safe, sufficient space, attractive, clean, well maintained, too cold, too hot, accessible to people with impairments, reflects the professional nature, adequate sound privacy, adequate visual privacy). The items were clustered into six groups labeled Location, Safety, Healthy Environment, Facility Space, Comfort, and Professional Nature.	Job satisfaction	Items adapted from Rehabilitation Job Satisfaction Inventory (Wright & Terrian, 1987) including 15 items, agreement with the statement on a 5-point scale, importance rating on a 3-point scale, the final score of job satisfaction was calculated from 4 items (satisfied with job, plan on staying, the best compared to past jobs, look forward to going to work); additional items: clients appreciate what I do, my decision to accept employment was affected by this agency's appearance and location, significant health problem in the past year, attempted to change job within the past year.	Correlational study	All six environmental factors were significantly correlated with the job satisfaction. Stepwise regression analysis revealed that healthy environment and safety are the two significant predictors of job satisfaction.	State rehabilitation agencies in 16 states in U.S.	315 counselors
Judkins S. (2003). Paediatric emergency department design: Does it affect staff, patient and community satisfaction? <i>Emergency Medicine, 15</i> (1), 63-67.	ED design	ED waiting and treatment areas dedicated to pediatrics, physical separation between pediatrics and adult ED, décor and entertainment facilities appropriate for children	Staff, physician satisfaction	- Questionnaire (individualized for each group, 5 for physician, 4 for inpatient staff, and 5 for ED staff), 5 point rating from 1 poor to 5 excellent, number and percentage of responses in each category	Before-after comparison (the month before and 6 moth after the move)	ED staff reported that the pediatric ED functioned better in the new area. General practitioners referred more patients to the new ED and expressed higher satisfaction level with the services. No effects were found in inpatient staff.	A major metropolitan teaching hospital in Australia	148 general practitioners, 38 inpatient staff, 67 ED staff
Lin, B. Y., Leu, W. J., Breen, G. M., & Lin, W. H. (2008). Servicescape: physical environment of hospital pharmacies and hospital pharmacists' work outcomes. <i>Health Care Management Review, 33</i> (2), 156-168.	Pharmacy environment	Perceptions of the ambient conditions and space/function of pharmacists' work environment Questionnaire developed from literature and focus groups with pharmacists, 45 items on dispensing areas [outpatient, emergency, inpatient], 16 items on pharmaceutical, 14 items on storage, and 12 items on administrative areas), items focused on ambient conditions (e.g. temperature, air quality, music, odor, lighting, texture) and space/function (e.g. crowding, equipment, furnishings, layout), 5-point scale, Cronbach's alpha .94 -.98	Job satisfaction Intention to leave Intention to reduce working hours Job-related stress	Four variables measured on a 0-100 scale	Correlational study, cross-sectional	Favorable perceptions of pharmacy physical environment were positively related to overall job satisfaction and negatively related to the intention to leave or reducing working hours. There was no relationship between perceptions of physical environment and job-related stress.	Hospital pharmacies in Taiwan	182 pharmacists

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
Morrison, W. E., Haas, E. C., Shaffner, D. H., Garrett, E. H., & Fackler, J. C. (2003). Noise stress and annoyance in a pediatric intensive care unit. <i>Critical Care Medicine</i> , 31 (1), 113-119.	Noise	Sound pressure levels recorded continuously by a Quest Advanced 1900 precision integrating logging sound level meter, weighted average sound pressure level (Leq in dBA), minimum and maximum sound level, auditory events (alarm, telephone, etc.)	Staff stress	Physiology measures - Heart rate (average HR [bpm], minimum, maximum HR for every half-hour period, percent of time in tachycardia [HR>100], # of episodes of ectopy [disturbance of the cardiac rhythm]), a portable cassette battery-driven Holter monitor (GE Marquette 8500 series, Milwaukee, WI) - Salivary amylase concentration, a citric acid impregnated cellulose sponge, salivary amylase field test kits. Psychology measures - Self-reported stress and annoyance, Specific Rating of Events Scale, nurses rated how stressed or annoyed "right now" on a scale -- 0 for "not at all stressful" or "not at all annoyed" to 100 for "most stress possible" or "most annoyance possible"	Correlational study, regression analysis	Higher Leq was a significant predictor of higher heart rate and greater percentage of time spent in tachycardia. Higher Leq was associated with higher stress and annoyance levels self-reported by nurses.	A PICU in a major US hospital	11 nurses
Rice, G., Ingram, J., & Mizan, J. (2008). Enhancing a primary care environment: A case study of effects on patients and staff in a single general practice. <i>British Journal of General Practice</i> , 58 (552), 465-470.	Primary care facility	Purpose-built facility vs. converted Victorian house (the old Victorian house was cramped and noisy, lacked privacy, had only basic level of comfort and decoration; the new purpose-built facility was more spacious, had more light, more modern appearance, and greater comfort and novel art works)	Staff satisfaction; Staff psychological symptoms	- Staff questionnaire Staff satisfaction score (summation of 12 items, range from 0 to 60); - General Health Questionnaire (GHQ-12)	Before and after comparison; repeated measurements	A total of 19 staff members completed all three surveys. Staff workplace satisfaction in the new building was higher for administrative and professionals staff, and the two groups combined. There was no notable difference in psychological health indicated by GHQ-12.	An urban primary care facility in UK	27, 24, and 23 staff members completed questionnaires two month before move, 4 months after move, and 11 months after move

Reference	Environmental feature		Outcome		Study design	Results	Setting	Sample
	Variable	Metric	Variable	Metric				
<p>Tyson, G. A., Lambert, G., & Beattie, L. (2002). The impact of ward design on the behavior, occupational satisfaction and well-being of psychiatric nurses. <i>International Journal of Mental Health Nursing</i>, 11 (2), 94-102.</p>	<p>Nursing ward design</p>	<p>Old ward design (two-story constructed in 1920s, rectangular plainness, orange brickwork, terracotta roofs, living areas on ground floor, sleeping accommodation above, open unit) New ward design (two wards--one ward, 16-bed unit, 4 self-contained sleeping areas each including 4 single bed rooms with toilet, bathroom and sitting area; another ward, two single rooms, two double rooms, 4 four-bed rooms)</p>	<p>Job burnout Job satisfaction Staff behavior</p>	<p>Questionnaire - Maslach Burnout Inventory (MRI) (Maslach & Jackson, 1986) (level of burnout and personal accomplishment, emotional exhaustion, depersonalization towards patients, 22 items, 6-point scale - Job Satisfaction (Warr et al, 1979), satisfaction with extrinsic and intrinsic features of the job as well as overall job satisfaction, 16 items, 7-point scale Interview - Open-ended questions of advantages and disadvantages of the new wards and a rating on 7-point scale (whether new wards were an improvement on the old wards) Observation - Observation in 5-min intervals; behaviors in four categories: interaction with patients, interaction with staff, engaged in solitary task-orientated behavior, other duties, percentage of behaviors in one category divided total number of behaviors.</p>	<p>Before-after study</p>	<p>The mean percentages of the interactions with patients that were positive increased in the new wards. Staff perceived that the new ward environment was better than the old environment. However staff burnout levels were increased in the new wards. It appeared that ill fit of organizational climate and physical environment could contribute to the increased burnout levels. The changes in job satisfaction were not significant.</p>	<p>A rural psychiatric hospital in Australia</p>	<p>Questionnaire: 37 nurses in old wards, 34 in new wards; Observation: 40 nurses in the old facility, 40 in the new facility</p>
<p>Varni, J., Burwinkle, T., Dickinson, P., Sherman, S., Dixon, P., Ervice, J.,...Sadler, B.L. (2004). Evaluation of the build environment at a children's convalescent hospital: Development of the Pediatric Quality of Life Inventory parent and staff satisfaction measure for pediatric health care facilities. <i>Journal of Developmental and Behavioral Pediatrics</i>, 25(1), 10-20.</p>	<p>Staff satisfaction with physical environment</p>	<p>Pediatric Quality of Life Inventory (PedQL) Built Environment Staff Module - three scales, 50 items: structure (18 items), facility aesthetics (11 items), work environment (21 items), answer keys from 0 "never happy" to 4 "always happy" converted to 0-100; scale score was the average of the items in the scale</p>	<p>Staff satisfaction with coworker relationship</p>	<p>PedQL Staff Satisfaction Coworker Module (4 items), answer keys from 0 "never happy" to 4 "always happy" converted to 0-100; scale score was the average of the items in the scale</p>	<p>Correlational study</p>	<p>Staff were not satisfied with the existing 30-year-old facility. Higher staff satisfaction with the built environment structure and aesthetics was associated with higher coworker relationship satisfaction.</p>	<p>A 30-year-old, 59-bed, long-term, skilled nursing facility dedicated to the care of medically fragile children with complex chronic conditions</p>	<p>72 staff members</p>

Matrix of relationships

		Outcome				
	Variable	Job satisfaction	Burnout	Staff stress	Turnover intent	Perception of physical
Environmental feature	Physical environment attractiveness (aesthetics)					
	Daylight					
	Noise					
	Patient room occupancy					
	Acuity-adaptable room (single room maternity care)					

 Note: Cells shaded in gray indicate the existence of evidence supporting relationships between environmental features and outcomes

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