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).	- 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)	**Design manipulation** - 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) **Measurement using architectural drawings and computer software** - 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).	- 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)	**Experimental manipulation** - 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).	- 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)	**Saliva sampling and radioimmunoassay analysis** - 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).	- Prescription filling time (Lin et al, 1988; Wietholter et al, 2009) - Pharmacist travel distance for filling prescriptions (Lin et al, 1988)	**Computer simulation** - 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) **Medical records** - Review of medication records (Wietholter et al, 2009) **Measurement on architectural drawings** - 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)	- Response time to patient calls (minute) (Guarascio-Howard, 2011) - Patient ratings of nurse response to calls (Donahue, 2009)	**Observation** - Shadowing of nursing activity (Guarascio-Howard, 2011) **Questionnaire survey** - Press Ganey score on nurses' promptness in response to patient calls (Donahue, 2009)

	Term	Definition	Metrics	Measurement method
	Staff travel (Time allocation, travel distance)	Physical movements (location, time, duration, frequency, activity type) of healthcare staff members (Shepley, 2002; Zborowsky, 2010).	- 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)	**Observation** - 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) **Work sampling study** with PDAs - 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) **Pedometer** - Electronic pedometer attached to the back of staff's belts (Shepley & Davies, 2003) (Donahue, 2009) **Indoor positioning system** - An positioning system tracked radio-frequency identification (RFID) badges worn by participating nurses (Hendrich, 2009) **Link analysis** - 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
	Surgeon/anesthesiologist performance	Performance of surgical tasks and anesthesia monitoring tasks (Liu et al., 2009; Miskovic et al., 2008; Sanderson, 2005).	**Anesthesiologist performance** - 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) **Surgeon performance** - 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)	**Simulation** - 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). **Questionnaire** - 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, & Goldriech, 2010)	- 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 (Gurascio-Howard & Malloch, 2007) - Staff perception of communication (Gurascio-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** - 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 (Gurascio-Howard & Malloch, 2007) - Direct observation with stop-watch (Ortega et al., 2009) **Audio recording** - Analysis of audiorecording of team communication (Gurascio-Howard & Malloch, 2007) **Interview** - Interviews regarding staff's perceptions on communication, technology, and teamwork (Gurascio-Howard & Malloch, 2007) **Questionnaire** - 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. *Journal of Biological Rhythms, 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. *American Journal of Nursing, 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. *Health Environments Research and Design Journal, 4* (2), 109-120.	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
Gurascio-Howard, L., & Malloch, K. (2007). Centralized and decentralized nurse station design: An examination of caregiver communication, work activities, and technology. *Health Environments Research and Design Journal, 1* (1), 44-57.	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. *Health Environments Research and Design Journal, 2* (2), 5-20.	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. *American Journal of Hospital Pharmacy, 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., Kruys, A., & Russell, W.J. (2009). Monitoring with head-mounted displays: Performance and safety in a full-scale simulator and part-task trainer. *Anesthesia & Analgesia, 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. *Health Environments Research and Design Journal, 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. *Surgical Endoscopy, 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. *Surgical Endoscopy, 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. *Journal of the American Medical Informatics Association, 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. *Technology and Health Care, 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. *Health Environments Research and Design Journal, 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. *Pharmacy World & Science, 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. *Anesthesia, 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). Predesign and postoccupancy analysis of staff behavior in a neonatal intensive care unit. *Children's Health Care, 31* (3), 237-253.	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). 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	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). Influence of nursing-unit design on the activities and subjective feelings of nursing personnel. *Environment & Behavior, 2* (3), 303-334.	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). Effects of computerized prescriber order entry on pharmacy order-processing time. *American Journal of Health-System Pharmacy, 66* (15), 1394-1398.	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-Hellmich, L., Morelli, A., & O'Neill, M. (2010). Centralized vs. decentralized nursing stations: Effects on nurses' functional use of space and work environment. *Health Environments Research and Design Journal, 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	Observation of place- and person-centered space use. - 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). Sound levels--portable decibel meter (Extech Model #407738) 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. On-line questionnaire, 35 questions assessing nurses' experienced workplace demand, control, and support based on Karasek and Theorell's (1990) Demand-Control-Support instrument	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-miunte 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