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⟨1066⟩ PHYSICAL ENVIRONMENTS THAT PROMOTE SAFE MEDICATION USE

INTRODUCTION

The physical work environment in healthcare settings is one of the most important potential contributors to medication errors. Data on medication errors reported to the United States Pharmacopeia (USP) Medication Error Reporting Program (2008) show that various physical attributes of the workplace affect human performance on the job. These attributes may help or hinder healthcare providers as they strive to deliver safe, high-quality care to every patient. As noted by the Institute of Medicine (IOM) in its landmark 2001 report, *Quality Chasm*, "Health care today harms too frequently and routinely fails to deliver its potential benefits."

This general chapter describes evidence-based standards for creating and maintaining a physical environment that supports and promotes accurate, safe medication use. The process of safe medication use involves multiple aspects, or stages: procurement, prescribing, transcribing, order entry, preparation, dispensing, and administration, as well as monitoring the medication's effects on the patient. A better understanding of these processes can form a solid foundation for improvement, allowing healthcare providers to reach optimal performance within the medication use system in various practice settings. This general chapter focuses on the characteristics of the physical environment that can promote accurate medication use. Standards are provided when justified by evidence and expert opinion, and a glossary of terms used in this general chapter is provided.

ORGANIZATIONAL SUPPORT

The leadership of a healthcare organization typically determines the operations, policies, and procedures that influence safety. The leaders also establish the workplace design and cultural environment, and they have a powerful influence on the espoused safety culture versus the enacted safety culture. For example, the organizational hierarchy can either enhance safety by encouraging the free flow of information and reinforcing safety behaviors, or can discourage and downplay any safety initiatives. Two reports are available that document issues related to organizational actions and culture as they affect patient safety and care: The IOM's 1999 report, *To Err is Human*, and the IOM's 2006 report, *Preventing Medication Errors*.

Accreditation agencies such as The Joint Commission (TJC), the National Integrated Accreditation for Healthcare Organizations (NIAHO), and the International Organization for Standardization (ISO) emphasize the roles of the organization and leadership in determining safety standards. TJC defines the critical function of leadership and holds the leaders accountable for their systems and processes, whereas NIAHO and ISO call for management review of both quality and safety by the governing body, with the goal of promoting high-quality, safe healthcare.

Organizational influence can be understood as falling somewhere on a continuum ranging from prescriptive controls, in the form of rules and procedures, to discretionary controls, which may rely solely on the individual's experience, according to James Reason (*Human Error*, 1990). Organizational controls that foster a safe environment should include, at a minimum, the reporting, analysis, and intervention plans necessary to shore up defenses against adverse medication events. Systems analysis of errors should include the organizational influences that ultimately affect the workforce at the unit level.

Leadership that is supportive and empowering, at all levels of the organization, should result in optimal physical work environments that help to prevent medication errors and promote accurate medication use. This approach can improve the performance of all persons involved in the medication use process. An organization that aligns leadership goals and resources to a strategic safety focus based on evidence will create safer systems for medication delivery. Although hospitals have been "designed" for patient care, there is a growing body of research that points to evidence-based design (EBD) for safe delivery of care. Other high-risk industries with a strategic safety emphasis share common characteristics, including the use of robust processes for improvement throughout organizations; this can lead to interventions based on scientific data and evidence.

MEDICATION SAFETY ZONES

In the medication use system, the degree of accuracy and safety accomplished is the end result of many interactions between humans, their physical work environments, and the equipment and technology they use. It is important to focus on areas of the work environment where (1) medications are prescribed; (2) orders are entered into a computer or transcribed onto paper; and (3) medications are prepared/compounded, dispensed, and administered. These work areas are commonly referred to as medication safety zones (MSZ). Examples include the work areas around a medication cart on a nursing unit; any location where prescribing decisions are made; the work space of an automated medication dispensing device; a pharmacy where prescriptions are prepared, inspected, and dispensed; and areas in

patients' homes where medications are prepared, consumed, or administered. The patient's bedside in the healthcare facility or home is another important MSZ that presents unique challenges.

The physical environment of any procedure room deserves special attention because of the increased noise levels, variable illumination, and other distractions. In this challenging setting, providers are making critical medication decisions that can influence whether a patient lives or dies. Also, medication safety zones should include the provision for areas that allocate space to incorporate equipment for the safe disposal of sharps (needles and syringes). Overall, in any MSZ, it is important to ensure that appropriate quantities of supplies are maintained; product expiration dates are checked routinely; and temperature-sensitive products are kept in the correct storage conditions.

Principles From Human-Factors Research

The research literature describes several principles that may be useful in planning the physical environment of the MSZ.

IMPORTANCE PRINCIPLE

Within the MSZ, important components should be placed in convenient locations. For example, information systems should be accessible within or near the MSZ so that drug information and patient data (e.g., lab results and vital signs) are readily available. Instructions about equipment function and troubleshooting should be located directly on or near the equipment to provide a quick answer to questions that arise.

FREQUENCY OF USE PRINCIPLE

Supplies and equipment that are used frequently should be easy to find and accessible. This reduces the likelihood that staff will create workarounds, in which suboptimal equipment/supplies are substituted for the recommended items.

FUNCTION PRINCIPLE

Displays, controls, or supplies related to a specific function should be grouped together. For example, syringes, needles, and alcohol swabs could be stored together in one drawer, and IV tubing and connectors that are used to prepare infusions could be placed together on the same shelf.

SEQUENCE OF USE PRINCIPLE

Items should be placed in an order that reflects the sequence of steps needed to perform the task correctly. For example, sterile gloves are in or with sterile dressing kits, and the items are arranged in sequence. This allows personnel to complete tasks quickly and correctly.

Bedside Workstations

Methods for performing workplace analysis are available. One important aspect is the medication administration areas at the bedside (in healthcare facilities or the patient's home), which should follow the same design as the centralized MSZ. Distractions are an even greater challenge at the bedside, and measures should be taken to minimize them whenever possible. Information and supplies should be kept accessible (according to the human-factor principles already discussed) and placed in an uncluttered area with adequate lighting. Sharps containers should be placed within easy reach for the provider, but out of high-traffic areas. Each bedside work station should be standardized in design, so that information and supplies do not need to be brought along when moving from one patient bed to another.

Lean Production

Maintaining an efficient, effective workplace reduces the likelihood of errors. One efficient approach to workspace design uses lean-production techniques to enhance desirable, value-added activities while eliminating undesirable activities that lead to waste during work processes.

Three lean-production techniques are as follows: (1) *Visual Controls*, i.e., keeping work processes and indicators in view so that personnel can see the status of tasks at a glance; (2) *Streamlined Layout*, i.e., optimizing the sequence of work processes through facility design; and (3) *Point-of-Use Storage*, i.e., storing supplies at the location where they will be used whenever possible so that personnel can perform tasks more efficiently.[1]

Simplification and Standardization

Making changes that simplify and standardize the patient-care environment decreases the cognitive load, reducing the likelihood of slips and lapses during routine tasks by minimizing decision and manipulation time. Standardization can be used for facility and room design, medical equipment, and medication-related functions (e.g., medication delivery, storage of patient-specific medications). Ensuring ready access to clinical information that is specific to the patient (or the drug) is essential for all areas in which personnel implement steps in the medication-use process.

Innovative Solutions

Another approach to optimizing the design of the MSZ is to involve personnel who perform the tasks on a routine basis. Workers may suggest innovative solutions to work station problems. To support innovation, it is advisable to incorporate flexibility into the MSZ design.

Forcing Functions

Constraint and forcing functions are an effective means of preventing errors, particularly for high-risk medications and situations. Forcing functions do not always refer to device design. The simplest of these do not require technology. One of the first forcing functions identified in healthcare was the removal of concentrated potassium from hospital units to eliminate the risk of inadvertent preparation of intravenous solutions with concentrated potassium, an error that has caused a small but stable number of deaths over the years.

Other examples would include sealing neuromuscular blockers in an intubation kit which lowers the chance of a paralyzing agent being administered to a patient without having access to ventilation support. Additionally, packaging an enteral product so it is physically unable to connect to an intravenous tubing luer lock connector would avert a wrong route error, even if the nurse was working in low-light conditions and initially misidentified the intended route for the tubing. The availability of medication safety technology is never a substitute for safe medication practices within an MSZ. Reports have warned of errors that result from ignoring or overriding safety checks, such as smart infusion pump drug libraries and alarms.

Work System Elements

CHARACTERISTICS OF INDIVIDUALS

Characteristics of the individual performing the work include his or her experience level, age, visual and hearing acuity, distractibility, and level of attention. Humans vary in their responses to the physical environment. In an ideal scenario, the physical environment could be modified on an individual basis. In that way, the environment could be adapted to match the needs of the current user, thereby optimizing the accuracy of his/her performance. Alternatively, the environment should be as supportive as possible to as wide a range of capabilities as possible.

SOUND AND NOISE

The Environmental Protection Agency (EPA) recommends peak sound levels of 45 dB during the day and 35 dB at night in hospitals. The World Health Organization (WHO) guidelines state that background sound levels in a patient room should not exceed 35 dB. The International Noise Council recommends maximums of 45 dB during the day and 20 dB at night for acute care areas. Ear protection is required when workers are exposed to sound levels averaging 90 dB.

The standard for sound levels in MSZs is set at 45 dB. This is intended to ensure that critical verbal information can be heard accurately. Healthcare providers should be sensitive to their individual need for quiet, depending on the task being performed, and they should have a quiet area available to promote accurate performance. The total elimination of noise in patient-care settings is not feasible or desirable. Patient counseling areas in pharmacies should include sound-reduction methods to enhance audibility and learning, for example, the use of a closed room.

Noise is recognized as a serious health hazard to hospitalized patients, and as a source of interference with effective work performance. Most studies of the effects of noise in the work environment have been conducted in non-healthcare settings. However, noise levels as a factor contributing to stress for nurses is increasingly being documented. In healthcare facilities, sources of noise can range from overhead paging systems, equipment alarms, heating, ventilation, and air-conditioning (HVAC) systems, plumbing, televisions, and radios to ice machines. Noise has been cited as one obstacle to the effective performance of nurses. An in-depth study developed a noise map of a hospital, and found sound levels of 55 dB, which is 10–20 dB above EPA recommendations, depending on the time of day. Average sound levels in other hospitals have been measured between 45 and 68 dB, with peaks between 85 and 90 dB. A study of sound levels during shift changes measured 113 dB.

The following sound-related features may affect accuracy when dispensing medication: predictability of the sound; controllability of the sound; type of task (simple vs. complex); multitasking; and distraction due to noise (which may mask environmental cues and the worker's internal voice, used to rehearse and recall important tasks). Out of 58 studies, 7 showed that noise improved performance, while 29 showed that it impaired performance. Unpredictable but controllable sounds and noise were found in one study to improve prescription filling accuracy, contrary to previous research. This may indicate that some environmental stimuli are needed to maintain proper alertness and attention of workers. Researchers are attempting to identify optimal levels of arousal due to sound and noise for people performing different kinds of tasks (e.g., Yerkes–Dodson law).

Noise and other sensory interference can be reduced by employing activities, tools, and principles developed by human factors and engineering experts; many of these principles are already being used by some healthcare organizations. The effects of these and other design improvements for nursing workspaces on patient outcomes and facility performance are being studied as part of a research project (*http://www.healthdesign.org/pebble*) sponsored by the Center for Health Design, a nonprofit research and advocacy organization. The project has found decreases in medical errors, as well as reductions in patient transfers, nosocomial infections, patient falls, and medication usage. When permitted by infection control guidelines, reducing noise by installing materials that absorb sound (e.g., ceiling and wall materials, and carpeting) can be accomplished at modest cost. Acoustical engineers can provide additional methods for noise reduction. Workers who don't have to respond to any audible signals such as telephone calls or alarms may be able to wear noise-canceling headphones and listen to music, provided that performance is not adversely affected.

ACTIVITIES AND TASKS PERFORMED

When designing an optimal physical environment that promotes accurate medication use, one should consider the activities and tasks that need to be performed. A poorly designed environment or other adverse conditions in the work area can lead to an unsafe adaptation of the procedures. For example, practitioners who have to listen to the constant barrage of equipment alarms that are not set within appropriate parameters (and are producing too many false alarms) may silence the alarms to reduce the noise. However, this limits the practitioner's ability to monitor the safety of the system. Similar situations occur with visual alarms and computer messages that are often ignored or overridden. In general, activities and tasks should be structured so they can be performed with the least amount of difficulty. If workarounds are detected, they should be investigated as an indication that the procedure or workflow is not suited for the task.

Multi-Tasking

The term "multi-tasking" originated in the computer engineering industry; it is the ability of a person to perform more than one task simultaneously. The human brain is wired differently in every individual; therefore, not everyone can multi-task successfully. The need to multi-task is common in all areas of the healthcare environment, whether on a nursing unit, in a pharmacy, in an operating room, or in a special procedure area. Some people can focus on performing more than one task at a time, whereas others cannot. In the human brain, multi-tasking involves linearly switching back and forth among different activities while actually completing one task at a time.

This can be problematic in healthcare settings, particularly if something unexpected happens in relation to one task while the individual is focused on the other task. These interruptions and distractions can lead to medication errors and other forms of patient harm. Another type of multi-tasking error is related to “mental stacking,” that is, when several items are under consideration at the same time. An excessive cognitive workload can lead to unintended consequences, and it is important to note that not all practitioners are able to handle established systems and processes in a particular physical environment.

Pharmacists and nurses are practitioners who typically multi-task. Although most prescriptions are prepared or administered one at a time, this does not mean that multi-tasking cannot occur. The work area should be designed to keep individual prescriptions separate while accommodating multi-tasking. Individuals vary in their abilities to perform sequential tasks versus multi-tasking. Currently there is not enough evidence to evaluate an individual's fitness to perform multi-tasking in healthcare settings, but human factors research in controlled laboratory settings suggests that in the future, it may be possible to assess and augment this skill in healthcare providers.

TOOLS AND TECHNOLOGIES IN THE PHYSICAL ENVIRONMENT

In the healthcare setting, tools and technologies that are used to perform the tasks can also interact with the physical environment to affect the likelihood of medication errors. Therefore, the design of the environment should account for the specific tools and technologies that individuals will use to complete their work. For instance, the physical layout of an operating room should accommodate the size, maneuverability, and required spacing of the many devices used during surgery. Tools and technologies should also meet ergonomic design standards.

Another example is that labels on medications are sometimes too small to display instructions for preparation, dispensing, or administration; when this occurs, alternatives should be considered. One alternative is to include Quick Response (QR) codes on the labels, which allow healthcare personnel with a web-enabled device (such as an iPad, iPhone, or Android-powered device) to access prescriptive information and handle the product correctly. QR codes are two-dimensional bar codes that, when read by an imaging device, bring the user directly to the website containing the needed information.

Additional factors that should be considered include equipment malfunction, downtime, and vibration.

Equipment malfunction: Any equipment that malfunctions, is damaged, or is lost should be reported to the supervisor immediately. In the case of malfunction, a decision should be made either to repair or to replace the item as soon as possible. In many cases, the item can be replaced rapidly, but some pieces of equipment take longer to disassemble and reinstall. Personnel should confirm that the equipment is in good working order before and after each use. A routine program of confirming equipment function should be in place.

Equipment downtime: The term “downtime” refers to periods of time when a system or item of equipment is unavailable. The outage, or downtime duration, is the length of time that the equipment fails to perform its primary function. The concept of downtime is commonly applied to computer networks and servers but can also be used in other environments when discussing equipment failures. These failures can occur for various reasons, including damage; design flaws; procedural error, i.e., improper use by humans; engineering issues, i.e., how the equipment is used and deployed; overload occurring when system resources are stressed beyond capacity; environmental problems with support systems such as heating, ventilation, and air conditioning (HVAC) and power; and scheduled downtime for maintenance, upgrades, or expansion. Service agreements are a common strategy for minimizing downtime and outages. Procedures should be in place to address downtime.

Equipment vibration: Vibration is a mechanical phenomenon in which oscillations occur around an equilibrium point. Although vibration may be desirable, usually it is undesirable, wasting energy and creating unwanted noise. As examples, the vibrational motions of engines, electric motors, or any mechanical device are typically unwanted and may result from imbalances in the rotating parts, uneven friction, imperfect meshing of gear teeth, and other factors. Careful design and proper installation can usually minimize unwanted vibrations.

DISTRACTIONS AND DISTRACTIBILITY INDEX

The healthcare work environment is replete with distractions and interruptions that can adversely affect work performance and lead to medication errors. Architects, engineers, and other professionals who play a role in workplace design have a responsibility to be educated about, and keenly aware of, this issue so they can design safe, ergonomically ideal workspaces. This approach should have a significant beneficial impact by counteracting the negative effects of interruptions and distractions on patient care. In general, MSZs should be located in areas where the potential for distraction and interruption is minimized. Nurses frequently cite distractions and interruptions as contributing to the incidence of medication errors. Distraction from competing tasks is likely to impair performance in several ways, such as sensory/perceptual interference (e.g., the nurse doesn't hear the alarm because a coworker interrupts with a question), cognitive cost of switching tasks (the nurse responds to an alarm more slowly because it takes time to reorient to the alarmed task after a coworker's question), or prospective memory failure (when returning to the task after the interruption, the nurse omits a step because of forgetting where he/she left off).

In addition, interruptions and distractions have been linked to higher rates of prescription dispensing errors in an ambulatory pharmacy. According to the 2008 USP MEDMARX Data Report, distractions continue to play a major role in medication errors, identified as a contributing factor in 45% of all medication errors in hospitals and health systems. However, interruptions and distractions can be prevented

or reduced by giving staff the ability to control and manage their exposure to these disturbances. Personnel can be allowed to adjust features of the MSZ to maximize their concentration and attention levels and to optimize their performance. Adjustable features include a work station that is protected from interruptions and distractions, such as a separate medication room, versus a mobile cart with workspace for those that are not adversely affected by distractions. Individuals have different levels of distractibility, and should be sensitive to their own need for a distraction-free work area. Heightened self-awareness of the adverse impact of interruptions and distractions can help minimize problems. Also, workers can be trained in how to avoid interrupting coworkers for non-urgent requests, particularly while their coworkers are performing medication-related tasks. In a pharmacy study, the most frequent source of interruptions was coworkers asking for assistance.

Techniques that may be effective for decreasing interruptions and distractions include visual cues (such as wearing orange safety vests) and physical barriers, such as preparing doses in a medication room. Personnel can also use checklists to focus or refocus their own attention on the task. Scientific research about distractions and interruptions in the physical environment is limited; therefore, additional studies are needed to identify evidence-based corrective actions that will promote safe medication use.

PHYSICAL ENVIRONMENT ELEMENTS

Factors in the physical environment, such as lighting, noise, temperature, layout, and workstation design, interact with human and task-related factors to influence the accuracy of medication use. The remainder of this general chapter focuses on providing guidance on the optimal environment to improve the performance of persons involved in the medication use process.

WORK SYSTEM DESIGN

According to the Systems Engineering Initiative for Patient Safety (SEIPS) model, five work systems—humans, tasks, technology and tools, organization, and environment—interact to affect employee, organization, and patient outcomes. Because these five work systems are closely interrelated, designers should consider all of the systems. Whenever one work element changes, there will be implications for the other elements. The entire work system needs to be well designed to optimize performance and ensure positive outcomes. Although this general chapter describes all the work systems, it focuses on recommendations for the physical environment.

Evidence-Based Design

Evidence-based design (EBD) is a field of study that draws upon the most reliable research data in planning the design of the workplace environment and equipment. EBD is closely related to the systematic hierarchy of evidence-based practice, and uses a systematic process of evaluating scientific research as the basis for design decisions that enhance human performance and reduce stress in the complex environment of healthcare. EBD intersects and combines the domains of ergonomics, human factors, usability, and cognitive psychology to arrive at the best possible work environment.

EBD principles are available to inform environmental design choices. In 2008, Ulrich and associates published a review of the research literature on evidence-based healthcare design, concluding that “The evidence indicates that well-designed physical settings play an important role in making hospitals safer and more healing for patients and better places for staff to work.” For example, major advances such as reduced infection rates have been linked to the design and location of sinks for hand washing, proper ventilation, and suitable materials for surfaces.

Application of EBD principles to equipment design is just as essential as applying these principles to the work environment. The use of EBD for intravenous pumps, feeding tubes, and patient-controlled analgesic devices has been described in recent years. Research continues to support the use of standardized fonts and labels for drug identification, as well as EBD for medication storage areas. In each decision regarding the complex healthcare work environment, stakeholders should draw upon the most substantial research evidence available and use it as a major guiding factor. Objects such as furniture, cabinetry, and fixtures should be selected after careful consideration of EBD goals and research. For example, it is ideal if furniture can be configured to create a sense of privacy and minimize visual and auditory distractions during medication transcription, preparation, dispensing, and administration. Furniture should be adjustable to meet a worker's ergonomic needs. In addition, surface contamination can be reduced by selecting nonporous surface materials with no joints or seams, allowing for ease of cleaning.

CHALLENGES IN THE PHYSICAL ENVIRONMENT

Ordering and Transcribing

Errors in ordering medications or transcribing medication orders are well documented in the research literature. Because errors made during these tasks can directly endanger patient safety, ordering and transcribing should be treated as high-risk activities within the healthcare environment. Manual methods of ordering and transcribing are dependent on human performance. Errors may result when the reader misinterprets handwriting flaws, abbreviations, or decimal points, or when there is frank misreading of handwriting. Faxed orders involve additional concerns, because legibility may be poor after transmission and printing.

Computerized systems for ordering, known as computerized physician order entry (CPOE), and transcription of orders by electronic means are not completely protected from the possibility of error. For example, electronic healthcare records have been cited for failures in usability and visual display, and may lack the customization necessary to order for specific populations, such as pediatric patients. Although the electronic transmission of data is considered more secure from errors of interpretation, the addition of decision support in CPOE has not been established as an evidence-based intervention that assures safety. At all times, applications of technology should undergo the same degree of scrutiny as other methods to prevent medication errors.

Preparation and Compounding

The preparation/compounding work area should be designed, arranged, and maintained to facilitate high-quality compounding that meets the standards of *Pharmaceutical Compounding—Nonsterile Preparations* ⟨795⟩ and *Pharmaceutical Compounding—Sterile Preparations* ⟨797⟩. The area for sterile drug preparation should be separate from the area for nonsterile drug preparation (see ⟨795⟩ and ⟨797⟩). Traffic in the preparation/compounding area should be kept to a minimum, with only authorized individuals allowed access. Lighting, temperature, and ventilation should be optimal to prevent decomposition of active pharmaceutical ingredients (APIs), excipients, and drug products. These measures can also ensure a workplace where personnel are not distracted by physical discomfort.

Humidity should be monitored and controlled, because drugs tend to degrade in the presence of moisture. Because of its effect on drug stability and integrity, the humidity in compounding and storage areas is second in importance only to temperature (see ⟨795⟩ and ⟨797⟩). A hygrometer should be placed on an interior wall, but not near an air-handling return, hot plate, or door entrance/exit, so that it will provide a representative reading of the relative humidity in the compounding area or storage facility.

The materials used for the floor, walls, shelving, cabinets, and ceiling should not retain dust, odors, or residues from the compounding activities. Also, the area should be free of dust-collecting overhangs (e.g., ceiling pipes, hanging light fixtures, and ledges). The actual work area should be level, smooth, impervious (free of cracks and crevices), and non-shedding, and the shelving and cabinets should be easy to clean.

Hazardous drugs should be prepared, stored, and handled by appropriately trained personnel under conditions that protect the healthcare workers and others who may come in contact with these drugs. Disposal of all hazardous drug wastes should comply with the applicable federal and state regulations. Any workers who perform routine custodial waste removal and cleaning activities in the storage and preparation areas for hazardous drugs should be trained in appropriate procedures to protect themselves and prevent contamination of the physical environment. This training should include procedures to be followed in the event of a spill.

For sterile compounding, the primary engineering control (PEC) unit should be placed in a location that will minimize noise and avoid conditions that could adversely affect its operation. For example, strong air currents from opened doors, personnel traffic, or air streams from the HVAC systems can disrupt the unidirectional airflow in open-faced workbenches. The PEC should be placed out of the traffic flow and in a position that will avoid disruption from the HVAC system and room cross-drafts. In general, all equipment should be selected and installed to create optimal working conditions, with minimal noise and sufficient lighting, so that personnel can perform accurate, high-quality work (see ⟨797⟩).

Dispensing

There are many potential distractions in dispensing areas of pharmacies and other areas where medications are dispensed. These distractions may include ringing telephones and interruptions from patients, other staff, visitors, and others. Distractions should be minimized or eliminated to the greatest extent possible. Although dispensing functions often require multi-tasking, it is optimal that only one prescription or medication order be prepared, processed, and checked at a time. The final check should be done by a pharmacist or an authorized, licensed professional in an area that is free of distractions. Additional points include the following:

- Proper illumination is necessary because the labels on some containers have very small or lightly colored print.
- Noise levels should be kept to a minimum (see *Table 2*), which may require moving noisy equipment to a different room, or at least using a partition for separation.
- Odors in the pharmacy setting should be controlled by using appropriate exhaust systems, which should be maintained properly and monitored periodically. Pharmacies contain a combination of odors resulting from the storage, preparation, and dispensing of the drugs themselves; odors also emanate from other items such as disinfecting agents.
- Temperature should be maintained at appropriate levels for the comfort of pharmacy personnel and for the stability of the pharmaceuticals.
- The pharmacy workspace should be designed to enhance workflow efficiency and to maintain safety throughout the entire dispensing process.

Administration

Some critically important MSZs for nurses include the medication preparation and administration areas. Information should be readily available in a user-friendly format that will facilitate the practitioner's synthesis of facts and data. Access to medication-related information should be efficient, with materials and records available at the proper sites. For example, a nurse may need both drug information and patient-specific data to make a decision about drug administration; therefore, these two sources should be near each other to support fact finding and/or decision making. The various information components within the space should be arranged according to specific principles that decrease distractions when seeking information and making decisions. Nurses also need to be aware of additional factors when administering medications, e.g., illumination, clutter, odor, noise levels, and temperature.

The Home Environment

The home healthcare environment differs from hospitals and other institutional environments in some important ways. For example, clinicians recognize that the homecare setting is the private domain of the patient. Thus the care they provide to each patient should be unique and individualized, based largely on that home setting. There may be situational variables in the patient's home that present risks to the patient and are difficult or impossible for the clinician to eliminate. For instance, hospitals have environmental safety departments to monitor air quality, as well as designers/engineers to ensure that the heights of stair risers are safe, but home healthcare providers are not likely to have the training or resources needed to assess and ameliorate such risks in the patient's home.

Yet the patient and caregiver still can promote a safe home environment by establishing proper storage, organization, and accessibility of medications, as well as adequate lighting in areas where drugs are administered. Several other physical elements also should be assessed to facilitate safe handling and administration of medications. There should be reliable telephone service to the home, an adequate area to prepare and administer medications (e.g., parenteral infusions), and intact, safe electrical outlets for any required equipment. All medicines should be stored in ways that facilitate both medication safety and compliance. The storage locations should be dry and cool. Medications needing refrigeration should be stored in areas where they will not freeze. All medications, whether prescription or over-the-counter, should be kept out of reach of children, pets, or mentally altered/impaired adults.

PHYSICAL ENVIRONMENT FACTORS

Sensory interference resulting from extreme temperatures, noise, poor lighting, glare-producing surfaces, interruptions, or clutter can adversely affect the working memory and job performance of healthcare practitioners. The guidelines described here for the physical environment should be applied to MSZs.

Illumination

Proper illumination levels can improve both accuracy and efficiency of performance. Prescription-filling accuracy improved significantly, from 96.2% to 97.4%, when lighting levels in a busy outpatient pharmacy were increased from 450 to 1460 lux (45–146 fc). One study found that pharmacists who rated lighting levels as at least adequate detected 38% more errors when filling prescriptions. In addition, as visual fatigue increases over a shift, increased light is needed. Pharmacists using task lights to increase illumination had a 10.7% reduction in product verification errors. A study of luminance in homes, offices, and public places found lower levels than recommended for reading, and also found that performance was related to age. Efforts should be made to prevent medication errors caused directly or indirectly by low lighting. For example, one incident report showed that poor lighting contributed to improperly connected patient-controlled analgesia (PCA) administration tubing, causing medication to run onto the floor, resulting in uncontrolled patient pain. Low lighting contributed to difficulty in seeing that the tubing was not connected properly. A study of lighting in a retail pharmacy revealed an error in strength and dosage form as dicyclomine 10-mg capsules were used to fill a prescription for 20-mg tablets. The light level at the shelf where the medications were stored was 220 lux (22 fc).

The recommendations described here take into consideration the need to work quickly and accurately during medication handling, the level of task visibility, and the comfort of personnel. Architects and lighting engineers can consult the Illuminating Engineering Society of North America (IESNA) reference “Lighting for Hospitals and Healthcare Facilities” for details about lighting medication areas. It is important to note that the illuminance levels recommended in the IESNA reference are below those listed in this guidance; the latter are higher because of evidence that lighting levels are inversely related to medication errors. Fluorescent cool white deluxe lamps or compact fluorescent lamps are recommended, because they have a color rendering index of 80 or more and are highly efficient compared to incandescent lamps. Providing the recommended color rendering index can help avoid misidentification of medications.

If illumination levels are below recommendations, task lighting is required in areas where critical visual tasks are performed. If task lighting is not available, then workers can cast shadows on the workspace, further reducing lighting levels. Critical tasks include reading handwritten prescriptions and small print on labels and inspecting medication dosage forms. Because individuals perceive lighting levels differently, adjustable 50-watt high-intensity task lights are recommended for situations where personnel encounter difficult-to-read prescriptions and product labels such as unit-dose package labels. Lighting levels are important for key healthcare providers involved in computer order entry (e.g., physicians or pharmacists), prescription filling, inspection, and patient counseling. Illumination levels for computer order entry areas should be at least 750 lux (75 fc). Higher levels [1000 lux (100 fc)] are recommended when handwritten orders are read.

Lighting should be positioned so there is no glare on the computer monitor that may make it difficult to read the screen accurately. Prescription preparation areas, medication inspection stations (for double-checking), and counseling areas should have illumination levels between 900 and 1500 lux (90–150 fc). These standards are all above the minimum of 200 lux (20 fc) for accurate reading of medication labels set by the American Society for Testing and Materials International (ASTM International). An ASTM International standard includes a legibility test requiring that the name and amount of the drug on the label be legible in 20 fc of light at a distance of about 20 inches (500 mm) by a person with 20/20 unaided or corrected vision. Lighting levels should be increased where the work force has an average age beyond 45 years to optimize legibility (general recommendation for treatment of presbyopia). Healthcare providers should also consider having a magnifying glass available to assist in the careful reading of labels with very small print and in situations where low lighting levels are unavoidable. Pharmacists using a magnification lens along with a task light reduced errors in product verification by 22% compared to a control group.

For nurses, key medication-related tasks that require good lighting include medication order review and medication selection, preparation, and administration. These tasks may take place in one or more locations on the nursing unit, such as the nursing station where patient charts are stored, the medication room, or a patient's room. Transitional lighting is recommended for medication areas on nursing stations and other patient care units to avoid dark and bright spots located next to dimly lit areas. Luminance should enable good color rendering (i.e., color rendering index of 80 or more) to assist with proper medication checking. Task lighting can help achieve appropriate levels of lighting and should be included on mobile medication carts (including those used with bar code medication verification systems). Glare on computer monitors should be controlled by ensuring that there are no light reflections that can wash out the screen and make it difficult to read.

Illumination levels for medication rooms located on nursing units should be at least 1000 lux (100 fc) based on the complexity of the task (e.g., reading small type on medication packages) and the need for accuracy and speed. The higher range of the lighting level should be used when the task requires reading small print. Lighting level recommendations are summarized in *Table 1*. Over time, lighting levels can decrease (e.g., by 25% over a 2-year period), so it is important to clean lighting fixtures routinely in order to maintain recommended luminance levels. Lighting levels should be measured on a quarterly basis. Burned out or flickering bulbs should be replaced promptly.

Table 1. Lighting Level Recommendations for Healthcare Settings

	Illumination Level	
Work Area	**Lux**	**Foot-Candle (fc)**
Computer order entry	1000	100
Handwritten order processing	1000	100
Medication filling and checking (pharmacy)	900–1500	90–150
Patient counseling (pharmacy)	900–1500	90–150
Sterile compounding and preparation	1000–1500	100–150
Pharmacy medication storeroom	500	50
Medication preparation area (e.g., nursing station)	1000	100
Medication administration work area (e.g., cart surface, patient room)	1000	100

Proper lighting is also essential at the point of care. Attempting to be patient- and family-friendly may run contrary to the necessary lighting conditions for safe medication administration. If practitioners administer medication at night under low luminance to avoid disturbing the patient or family, this an unsafe practice. Task or spot lighting should be available so practitioners can visually confirm that they have the correct patient (by reading armband or other identification technology), and so the medication and administration site is not compromised. Compact fluorescent lamps take time to come to the correct lighting level. Therefore, no critical tasks should be performed until the light is working at its rated level.

Sound and Noise Recommendations

For hospitals, the Environmental Protection Agency (EPA) recommends peak sound levels of 45 decibels (dB) during the day and 35 dB at night in hospitals. The World Health Organization (WHO) guidelines state that background sound levels in a patient room should not exceed 35 dB. The International Noise Council recommends limits of 45 dB during the day and 20 dB at night for acute care areas. Ear protection is required when workers are exposed to sound levels averaging 90 dB. Sound level recommendations are shown in *Table 2*.

Table 2. Peak Sound Level Recommendations

Work Area	Source[a]	Sound Level (dB)
Hospitals (daytime)	EPA	45
Hospitals (nighttime)	EPA	35
Patient room	WHO	35
Acute care areas (daytime)	INC	45
Acute care areas (nighttime)	INC	20
Ear protection required	INC	90 (average)
Medication safety zones	—	50

[a] EPA, Environmental Protection Agency; WHO, World Health Organization; INC, International Noise Council.

The standard for sound levels in MSZs is set at 45 dB, which is intended to ensure that critical verbal information can be heard accurately. However, this will be exceeded in many typical pharmacy dispensing and compounding areas. Healthcare providers should be sensitive to their individual needs for quiet, depending on the task being performed, and they should have a quiet area available to promote accurate performance. The total elimination of noise in patient-care settings is not feasible or desirable. Patient counseling areas in pharmacies should include sound-reduction methods (e.g., use of a closed room) to enhance audibility, learning, and privacy.

Excessive noise is recognized as a serious health hazard. Its effect on hospitalized patients and its possible interference with effective work performance by clinicians should be considered. Most studies of the effects of noise in the work environment have been conducted in non-healthcare settings. However, noise levels are being documented more often as a contributor to stress for nurses. In healthcare facilities, sources of noise can include overhead paging systems, equipment alarms, heating, ventilation, air-conditioning (HVAC) systems, plumbing, televisions, and radios to ice machines. Noise has been cited as one obstacle to the effective performance of nurses. An in-depth study developed a noise map of a hospital, and found sound levels of 55 dB, which is 10–20 dB above EPA recommendations, depending on the time of day. Average sound levels in other hospitals have been measured between 45 and 68 dB, with peaks between 85 and 90 dB. A study of sound levels during shift changes measured 113 dB.

Accuracy when dispensing medication can be affected by specific characteristics of the sound/noise, e.g., whether it is predictable and whether it can be controlled. These factors may mask environmental cues and the worker's internal voice, used to rehearse and recall important tasks. Out of 58 studies, 7 showed that noise improved performance, while 29 showed that it impaired performance. Unpredictable but controllable sounds and noise were found in one study to improve prescription filling accuracy, contrary to previous research. This may indicate that some environmental stimuli are needed to maintain proper alertness and attention of workers. Researchers are attempting to identify optimal levels of arousal due to sound and noise for people performing different kinds of tasks (e.g., Yerkes–Dodson law).

The adverse effects of noise and other sensory interference can be reduced by using activities, tools, and principles developed by human factors and engineering experts. Many of these principles and tools are already being used by some healthcare organizations. Researchers are studying these and other design characteristics of nursing workspaces to assess their effects on patient outcomes and facility performance; one study is sponsored by the Center for Health Design, a nonprofit research and advocacy organization, and a network of 11 healthcare providers (*http://www.healthdesign.org/pebble*). The data have shown reductions in medical errors, patient transfers, nosocomial infections, patient falls, and medication usage. Reducing noise by installing materials that absorb sound (e.g., ceiling and wall materials, and carpeting), when permitted by infection control guidelines, can be accomplished at modest cost. Acoustical engineers can provide additional methods for noise reduction. In addition, workers who do not have to respond to any audible signals such as telephone calls or alarms may be able to wear noise-canceling headphones and listen to music, provided that performance is not adversely affected.

Odor

Areas where pharmaceuticals are stored or manipulated tend to have an odor that is characteristic of the respective drugs. These odors often can be minimized by using appropriate air handling/exhaust systems. Indoor environmental quality (IEQ) can be related to chemicals and other sources. The odors found in almost any working environment may result from caulks, sealants, coatings, adhesives, paints, varnishes, stains, wall coverings, cleaning agents, fuels and combustion products, carpeting, vinyl flooring, fabric materials, air fresheners, and other scented products, as well as personal products of employees (e.g., perfumes, shampoos, and others). If these odors are not controlled, IEQ problems can arise, especially if the building's ventilation system is improperly designed and/or poorly maintained. IEQ can be improved by installing appropriate exhaust systems to remove the odors emanating from drug products. This may also include “snorkel exhaust” facilities close to where the drug products are manipulated, as well as cabinet-type exhaust hoods. Other measures that may be helpful include establishing perfume-free zones, prohibiting smoking, and not allowing food storage or eating in the immediate area. The practice of introducing pleasant odors in the workplace may or may not be beneficial, but managing the response to odors and irritants is critical to maintaining the health and well-being of workers.

Temperature Controls and Humidity

Temperature control is important for drug stability and for the comfort of personnel. In a room where equipment is present (e.g., laminar air flow hoods), heat tends to be generated, and therefore, appropriate temperature control measures should be designed and implemented.

In some situations such as compounding, it is important to control humidity and thereby minimize static electricity in powders, packaging, and other dosage forms (see ⟨795⟩ and ⟨797⟩). Humidity control is also important for related technologies, such as computers, tablets, and automated dispensing machines. The core temperature of the central processing unit in computers should be between 10° and 32° C, and the ideal humidity index is between 30% and 50%.

Physical Design and Organization of Workspace Assessment

The design of the work environment influences the ability of providers to effectively use information and accurately perform tasks. The height of counters, height of shelving for storage of supplies, and lighting changes in lower drawers and cabinets that decrease visibility of products can contribute to errors if improperly adjusted. The effective integration of adjustable fixtures and appropriate counter heights, with the use of mobile carts, can improve efficiency as well as safety. Work counter clutter or lack of sufficient space to perform key tasks is typically an indicator of disorganization and poor planning. One study found that more dispensing errors occurred when medication storage containers were placed on shelves in a cluttered fashion (<1 inch between distinct drugs). When choosing appropriate furniture, an evidence-based-design furniture checklist may be used to make informed investment decisions and improve healthcare outcomes (see *Table 3* for a complete checklist).

Table 3. Evidence-Based Design Checklist

Findings	Evidence-Based Design Goals and Features[a]
	1. Reduce surface contamination linked to healthcare associated infections A. Surfaces are easily cleaned, with no surface joints or seams. B. Materials for upholstery are impervious (nonporous). C. Surfaces are nonporous and smooth. 2. Reduce patient falls and associated injuries A. Chair seat height is adjustable. B. Chair has armrests. C. Space beneath the chair supports foot position changes. D. Chair seat posterior tilt angle and seat back recline facilitate patient egress. E. Chairs are sturdy, stable, and cannot be easily tipped over. F. Rolling furniture includes locking rollers or casters. G. Chairs have no sharp or hard edges that can injure patients who fall or trip. 3. Decrease medication errors A. Lighting fixtures should provide 90–150 foot-candle illumination and an adjustable 50-watt high intensity task lamp for furniture with built-in lighting that is used in a medication safety zone. B. Furniture is configurable to create a sense of privacy to minimize visual distractions and interruptions from sound and noise during medication transcription, preparation, dispensing, and administration activities. 4. Improve communication and social support for patients and family members A. Furniture can be configured into small flexible groupings that are easily adjusted to accommodate varying numbers of individuals in a variety of healthcare settings. B. Wide-sized and age variations are supported. C. Acoustic and visual patient privacy are supported. 5. Decrease patient, family member, and staff stress and fatigue A. Materials suggest a link to nature. B. Appearance is attractive and noninstitutional. C. Furniture is tested for safe and comfortable use by all, including morbidly-obese individuals. 6. Improve staff effectiveness, efficiency, and communication A. Furniture is easily adjustable to individual worker's ergonomic needs. B. Design enables care coordination and information sharing. C. Materials are sound absorbing. 7. Improve environmental safety A. Materials do not contain volatile organic compounds (VOCs), such as formaldehyde and benzene. 8. Represent the best investment

Findings	Evidence-Based Design Goals and Features[a]
	A. Reflect and reinforce the organizational mission, strategic goals, and brand. B. Integrate new with existing furniture and objects for facility renovations projects. C. Pieces can be flexibly reconfigured and moved to support changing and emerging missions. D. Provide casters or glides to reduce floor damage. E. Check that there are no protuberances that may damage walls; check chair rail heights. F. Manufacturer provides results of safety and durability testing. G. Manufacturer describes the specific evidence that has been used to design the product. H. Manufacturer includes a warranty appropriate to use, such as furniture used all day, every day. I. Replacement parts are available. J. Repair can be done in the healthcare facility. K. Manufacturer or local dealer can assist with furniture repair and refurbishing. L. Environmental services/housekeeping staff can easily maintain furniture. M. A Group Purchasing Organization (GPO) can be used when purchasing furniture.
Findings Scale: Present (+), Absent (−), More Information Needed (?), Not Applicable (N/A).	

[a] Malone EB, Dellinger BA. *Furniture Design Features and Healthcare Outcomes*. The Center for Health Design; 2011 (see https://www.healthdesign.org/chd/research/furniture-design-features-and-healthcare-outcomes).

METHODS FOR ASSESSING THE PHYSICAL ENVIRONMENT

Illumination

An illuminance meter, also referred to as a light level meter or photometer, is an instrument that consists of a photodetector (with a digital or analog display) that measures illuminance in lux or foot-candles (fc). Lighting levels should be evaluated in all MSZs using point illuminance measurements. To do this, the photodetector should be placed in the area where the critical medication task is performed (e.g., medication inspection at a work counter), with the worker standing in a normal working position when the measurement is taken. In medication storage areas, measurements should include light levels at the top, middle, and bottom shelves, because light levels depend on the distance from the lighting source. Photometers are commercially available, or management engineers may be able to provide them, and they should be recalibrated annually.

Illumination levels also can be measured using a smart phone “Light Meter” application (app). These apps are easy to use and inexpensive. They are simply downloaded to a Smartphone, and after clicking on the app, the camera function is pointed to a lighted area/surface and the on/off button is pressed. The device takes measurements and also provides a description of the activities for which those light levels are appropriate. The apps can be calibrated and the sensitivity adjusted, with readouts in either lux or fc.

Sound Levels

Sound level meters capable of reading from 30 to 130 decibels on the A scale (dBA) should be used to measure sound levels. The A scale is commonly used when measuring decibels because it most closely represents what the human ear hears in terms of loudness. The meters should be calibrated prior to each use. Measurements are taken while standing in a working position, using the instructions provided in the manual for the specific sound meter. Type 1 or Type 2 meters have acceptable levels of accuracy. Sound levels also can be measured easily and inexpensively by using a Smartphone app. The app is downloaded to a Smartphone, and the readout options are selected. The measurement is activated, and it continues to provide a complete readout of frequency (*x*-axis) and decibel sound pressure level (*y*-axis) in real time.

Odor Detection

Odors can be detected by individuals, but this approach is very subjective. Some odors indicate the presence of a specific chemical entity or moiety. However, appropriate measuring devices for use in a work environment may not be available or practical. Consequently, it may be necessary to select a team of individuals to categorize what is acceptable and what is not acceptable in terms of odors in the work environment. Appropriate HVAC systems may play a role in reducing odors.

Temperature/Humidity Measurement

Temperature is typically measured with digital thermometers, and humidity is measured with hygrometers. In both cases, a recording instrument (e.g., recording thermometer) offers the advantage of documentation.

SUMMARY

As early as the 19th century, Florence Nightingale identified the importance of physical environments for patient healing, but only recently was it established that the physical environment can support the performance of critical tasks by healthcare personnel to protect the patient from iatrogenic harm. Currently, medication errors are recognized as complex, multifactorial, and system dependent, and full scientific understanding of error prevention has proven elusive. However, Nightingale's counsel, “above all, do no harm,” compels us to use the most up-to-date evidence for safe practices in healthcare to prevent errors and protect the patient. Aspects and considerations of the physical work environment discussed in this general chapter are not exhaustive, but can serve as a stimulus for the assessment of existing work spaces and for consideration of the latest evidence from human factors science in the design of new facilities. The remaining constituent not discussed in this general chapter is the healthcare provider working in arduous conditions who may, with the best intent, contribute to patient harm through inadvertent actions in substandard conditions. The physical work environment should be structured to support and promote safe delivery of care and prevent harm to patients while also bolstering the practice of healthcare by clinicians.

GLOSSARY OF TERMS

Administering:
The preparation, directly prior to use, of a pharmacologic or other therapeutic agent for ingestion, injection, insertion, or application.

Color rendering index (CRI):
An expression of how a light source affects the color appearance of objects or humans, compared to how they would appear under a reference light source.

Compounding:
The preparation, mixing, assembling, altering, packaging, and labeling of a drug, drug-delivery device, or device in accordance with a licensed practitioner's prescription, medication order, or initiative based on the practitioner/patient/pharmacist/compounder relationship in the course of professional practice.

Constraint:
A rule stating under what conditions an action is allowed or prohibited. Constraints are used in designing procedures or tools to prevent unsafe practices.

Crowding:
A condition that occurs when multiple workers use the same workspace, adversely affecting the amount of space available for each person and also increasing the negative factors of distractions, interruptions, and noise.

Decibel:
A unit used to measure the intensity of a sound by comparing it with a standard level on a logarithmic scale, thereby indicating the degree of loudness. The A scale is commonly used when measuring decibels, because it most closely represents what the human ear perceives in terms of loudness.

Dispensing:
The act of providing a medication or prescription order; to fill a prescription.

Distraction:
An external stimulus that occurs when a person is engaged in a task or activity that causes a cognitive or emotional disturbance, but does not result in the discontinuation of the activity, such as a telephone ringing or question from a coworker.

Ergonomic design:
Arrangement of a workspace to accommodate each individual's capacities and limitations, allowing them to work safely and efficiently. This includes an optimum ambient environment and adjustable furniture.

Forcing function:
An aspect of a design that prevents a target action from being performed, or that allows its performance only if another specific action is performed first.

Human factors:
The scientific discipline concerned with interactions among humans and other elements of a system, and the profession that applies the theory, principles, data, and methods to design systems that optimize human well-being and overall system performance.

Illumination level:
The quantity of light energy reaching an area as measured (in lux or foot-candles) by a photometer with an illuminance sensor; this indicates brightness. A lux is a unit of illuminance, measured in lumens per square meter. A foot-candle (fc) is lumens/square foot, and is also commonly measured by light meters. The term candela replaced fc as the International System (SI) measure of luminous intensity and represents 1 lumen/steradium (lm/st).

Interruption:
The cessation of productive activity before a task is completed, caused by an externally imposed stimulus.

Lean production:
High-quality work output achieved while eliminating waste and decreasing resources used, time spent, and errors.

Medication safety zone:

A critical area where medications are prescribed; orders are entered into a computer or transcribed onto paper documents; or medications are prepared/compounded or administered. The characteristics of an optimal physical environment for accurate medication use will apply to MSZs.

Multi-tasking:

The ability of human beings to perform multiple tasks simultaneously.

Noise and sound:

Noise is defined as an auditory stimulus that bears no informational relationship to the task at hand. Sound is a change in volume that has some informational relationship to the task at hand. A quiet work environment is defined as an area where noise is absent and the worker is free from disturbance.

Override:

To neutralize or counteract the action of an automatic control.

Photometer:

An instrument for measuring photometric quantities such as illuminance.

Physical environment:

The surroundings that can affect one or more human senses.

Workaround:

A plan or method used to circumvent a problem (as in computer software) without eliminating it.

Working conditions:

A set of factors that include the physical environment, workforce staffing, workflow design, personal/social factors, and organizational characteristics.

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[1] Sanders MS, McCormick EJ. *Human Factors in Engineering and Design*. New York: McGraw-Hill; 1993.

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<1066> PHYSICAL ENVIRONMENTS THAT PROMOTE SAFE MEDICATION USE	Diana Kwan Associate Scientific Liaison	HSQ2020 Healthcare Safety and Quality

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