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Sound Control for Improved Outcomes in Healthcare Settings

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Abstract

Objective: The purpose of this paper is to examine how different aspects of sound—noise, speech privacy, speech intelligibility, and music—impact patient and staff outcomes in healthcare settings and the specific environmental design strategies that can be used to improve the acoustical environment of healthcare settings.

Methods: This paper provides a literature review of peer-reviewed journal articles, research reports, and books published in medicine, psychology, architecture, and acoustics publications. Keywords used to search for articles included noise in hospitals, reverberation, sleep, patient privacy, HIPAA, speech intelligibility, speech security, and music.

Key findings: Hospitals are extremely noisy, and noise levels in most hospitals far exceed recommended guidelines. The high ambient noise levels, as well as peak noise levels in hospitals, have serious impacts on patient and staff outcomes ranging from sleep loss and elevated blood pressure among patients to emotional exhaustion and burnout among staff. Poorly designed acoustical environments can pose a serious threat to patient confidentiality if private conversations between patients and staff or between staff members can be overheard by unintended listeners. At the same time, a poor acoustical environment impedes effective communication between patients and staff and between staff members by rendering speech and auditory signals less intelligible or detectable. This has serious implications for patient safety. A well-designed acoustical environment is critical in addressing these problems related to noise and communication of information. Noise levels can be effectively reduced by providing single-patient bedrooms, installing high-performance sound-absorbing acoustical ceiling tiles, and removing or reducing loud noise sources on hospital units. Also, acoustical ceiling tiles improve speech intelligibility by reducing sound reverberation and increase speech privacy by reducing sound propagation into adjoining areas. Another measure for increasing patient confidentiality is providing private rooms enclosed with walls that go up to the ceiling, thereby preventing voice travel through ceilings in spaces where private patient information is likely to be shared. A large body of research also shows that music therapy is effective in reducing anxiety and distress among patients in many different types of healthcare settings.

Conclusions: Sound control is critically important in healthcare settings, and different environmental design strategies have proven successful in mitigating negative effects of noise while allowing effective yet private verbal communication.

Introduction

Sound, in its different manifestations, can have profound impacts on patients, staff, and visitors in hospitals—ranging from soothing and therapeutic to stressful and disturbing. It is well-established that most hospitals are extremely noisy, well-exceeding recommended guidelines for noise levels (Busch-Vishniac et al. 2005). Noise, which is widely defined in the research literature as "unwanted sound," can be detrimental to patient and staff health. Another aspect of sound—speech intelligibility and audibility—is essential to communication between patients and staff and between staff members in hospitals. On the other hand, if confidential patient information being discussed between patient and staff members or between staff members is overheard by others, it can pose a serious breach of patient confidentiality, and issues of speech security and speech privacy come to the fore. These different aspects of sound, ranging from stressful noise to pleasant music and speech intelligibility to speech privacy, suggest the importance of designing and controlling the environment to prevent the transmission of unwanted sound yet maximize speech intelligibility between persons who need to communicate with each other.

Different aspects of sound that impact patients, staff, and visitors in hospitals:

- Noise
- Speech privacy
- Speech intelligibility
- Music

These issues associated with sound control and transmission are interrelated, and different environmental design strategies have proven successful in mitigating negative effects of noise while allowing effective verbal communication. The purpose of this paper is to examine how these different aspects of sound—noise, speech privacy, speech intelligibility, and music—impact patients and staff in healthcare settings and the specific environmental design strategies that can be used to improve the acoustical environment of healthcare settings.

Noise in healthcare settings

There is a large body of literature that clearly spells out the problem that is pervasive in hospitals the world over—hospitals are extremely noisy. The World Health Organization (WHO) guideline values for continuous background noise in hospital patient rooms are 35 dB(A) during the day and 30 dB(A) at night, with nighttime peaks in wards not to exceed 40 dB(A)[i] (Berglund et al. 1999). Busch-Vishniac and colleagues (2005) examined hospital noise levels reported in thirty-five published research studies over the last forty-five years. They found that not one published study reported noise levels that complied with the WHO guidelines for noise levels in hospitals.

Further, hospital noise levels have been rising consistently since the 1960s. The background noise levels in hospitals rose from 57 dB(A) in 1960 to 72 dB(A) today during daytime hours, and from 42 dB(A) in 1960 to 60 dB(A) today during nighttime hours (Busch-Vishniac et al. 2005). (Note that the decibel is a unit for quantifying sound pressure intensities or loudness levels based on a *logarithmic* scale. Therefore, a doubling of sound intensity would result in a 3 dB(A) increase in sound-pressure levels for diffuse sound fields. However, with respect to human hearing, a 10 dB(A) increase would be perceived as an approximate doubling of loudness. Accordingly, a 60 dB(A) sound is perceived as roughly four times as loud as a 40 dB(A) sound, despite having a pressure level 100 times higher.)

Further, many studies indicate that peak hospital noise levels often exceed 85 dB(A) to 90 dB(A) (Aaron et al. 1996; Balogh et al. 1993; Blomkvist et al. 2005; Cureton-Lane and Fontaine 1997; Guimaraes et al. 1996; Holmberg and Coon 1999; Kent et al. 2002; Tijunelis, Fitzsullivan, and Henderson 2005). Noises from alarms and certain equipment that exceed 90 dB(A) (for example, portable X-ray machine) are comparable to walking next to a busy highway when a motorcycle or large truck passes. Federal workplace

- Hospitals the world over are extremely noisy places.
- Hospital noise levels well exceed World Health Organization guideline values of 35 dB(A) during the day and 30 dB(A) at night in patient rooms, with recommended night time peaks of 40 dB(A).
- Peak hospital noise levels often exceed 85 dB(A) to 90 dB(A).

safety standards list 85 dB(A) as the safe maximum level of noise exposure for an eight-hour shift without ear protection (National Institute for Occupational Safety and Health 1998). Another way of characterizing the extraordinary loudness of common hospital sounds is to consider that an 85 dB(A) noise is 100,000 times higher in sound pressure than the recommended daytime level of 35 dB(A) for patient spaces. It is not surprising that high noise levels in hospitals have serious implications for staff and patient health and well-being.

Impacts of noise on patients

Considerable research has been conducted on the negative impacts of noise on patients and staff in hospitals. In addition to being a source of annoyance, loud noises in hospitals have been linked to sleep disturbance and arousals among patients. Studies conducted among neonatal intensive care (NICU) patients (Strauch, Brandt, and Edwards-Beckett 1993), pediatric and adult patients (Schnelle et al. 1993; Aaron et al. 1996; Parthasarathy and Tobin 2004; Freedman et al. 2001) have identified noise as the source of awakenings and sleep disruptions among patients. However, along with noise, other factors such as patient-care routines also contribute to sleep disturbance among patients and must be addressed as part of a comprehensive intervention to improve sleep (Freedman et al. 2001; Gabor et al. 2003).

Quiet time is especially important in NICU environments where loud noise levels decrease oxygen saturation (increasing need for oxygen support therapy), elevate blood pressure, increase heart and respiration rate, and worsen sleep (Slevin et al. 2000; Johnson 2001; Zahr and de Traversay 1995). There is some evidence that noise negatively impacts wound healing. In one study, patients stayed longer in the hospital after a cataract surgery during a period when noise levels were higher due to construction (Fife and Rappaport 1976). Also, Minckley (1968) found that when noise levels were high (more than 60 dB(A)), more medications were required by surgery patients post recovery.

Impacts of high noise levels on patients:

- Annoyance
- Sleep disruption and awakening
- Decreased oxygen saturation, elevated blood pressure, increased heart and respiration rate among neonatal intensive-care patients
- Decreased rate of wound healing
- Higher incidence of rehospitalization

A recent study in Sweden assessed the impact of modifying room acoustics (by switching between sound-absorbing ceiling tiles and sound-reflecting ceiling tiles) of an intensive coronary-care unit (CCU) on patient and staff outcomes (Hagerman et al. 2005; Blomkvist et al. 2005). During the good acoustical conditions (when sound-absorbing ceiling tiles were installed), pulse amplitudes were lower among patients in the acute myocardial infarction groups and unstable angina pectoris groups as compared to the bad acoustical conditions (when sound-reflecting ceiling tiles were installed). Patients were also more satisfied with the care provided by the staff during the good acoustic condition (Hagerman et al. 2005). Importantly, the incidence of rehospitalization was higher among patients treated during the bad acoustic conditions.

Impacts of noise on staff

Noise can be a source of stress for hospital staff and may interfere with their ability to work effectively. In the Swedish study on the impact of room acoustics, the researchers found that, during better acoustical conditions, staff experienced less work demands and reported less pressure and strain (Blomkvist et

al. 2005). Topf and Dillon (1988) found that noise-induced stress was related to emotional exhaustion and burnout among critical-care nurses. Morrison et al. (2003) found that noise was strongly related to stress and annoyance among nurses. In another study, healthcare staff perceived that the excessively high noise levels in the workplace interfered with their work and also impacted patient comfort and recovery (Bayo, Garcia, and Garcia 1995).

Little research has examined the impact of noise on healthcare staff performance, and the results are conflicting. Laboratory studies of non-healthcare groups have found that noise often does not impair task performance when there is incentive to increase effort or pressure to maintain exacting standards. The laboratory findings suggest that adequate performance during noise is maintained by increasing effort, as evidenced by heightened cardiovascular responding and other physiological mobilization (Parsons and Hartig 2000). The research implies the possibility that healthcare staff may be able to maintain exacting performance during some noisy situations, but at the cost of exerting greater effort and becoming more fatigued.

Impacts of high noise levels on staff:

- Increased perceived work pressure, stress, and annoyance
- Increased fatigue
- Emotional exhaustion and burnout
- Difficulty in communication possibly leading to errors

A few studies have examined work performance by anaesthetists and surgeons under different sound conditions (e.g., quiet versus simulated noisy conditions) and found that noise did not significantly worsen performance (Moorthy et al. 2004; Hawksworth, Sivalingam, and Asbury 1998). However, one study found that short-term memory and mental efficiency declined among anesthetists working under typical operating room noise conditions (noise levels over 77 dB(A)) (Murthy et al. 1995). The investigators found that, under these conditions, the threshold level for speech reception increased by 25 percent suggesting that speech communication was possible only by raising one's voice and, at the same time, speech discrimination reduced by 23 percent (Murthy et al. 1995). Clearly, such conditions may impact errors by hospital staff and have serious implications for patient safety.

Why are hospitals noisy?

There are two main reasons why hospitals are noisy. First, there are many noise sources present, and, second, environmental surfaces in hospitals—walls, floor, and ceiling—tend to be sound-reflecting rather than sound-absorbing (Ulrich et al. 2004; Ulrich 2003). Sounds contributing to the loud noise levels in hospitals come from mechanical equipment in use—alarms, paging systems, telephones, computer printers, ice machines, staff conversations, and noises generated by roommates and visitors. Many studies have found that staff conversation in particular is a major source of loud noises on the hospital unit (Allaouchiche et al. 2002; Bentley, Murphy, and Dudley 1977; Bayo, Garcia, and Garcia 1995).

The presence of hard sound-reflecting surfaces in the hospital tends to aggravate the noise problem in hospitals. Sound-reflecting surfaces cause noise to propagate considerable distances, traveling down corridors and into patient rooms, and adversely affecting patients and staff over larger areas (Ulrich 2003). Sound-reflecting surfaces typical of hospitals cause sounds to echo, overlap, and linger or have long reverberation times (Cole, Blomkvist, and Ulrich 2005; Blomkvist et al. 2005). Reverberation is the persistence of sound in an enclosed space, resulting from multiple reflections after a sound source has stopped. The reverberation time of a room is the time it takes for

Why are hospitals noisy?

- There are many loud noise sources present in hospitals.
- Sound-reflecting rather than sound-absorbing environmental surfaces cause sounds to have long reverberation times.

sound to decay by 60 dB(A) once the source of sound has stopped and is largely determined by the presence of sound-absorbing materials in the room (Joint Subcommittee on Speech Privacy of the Acoustical Society of America, Technical Committees for Architectural Acoustics and Noise; Institute of Noise Control Engineering; and National Council of Acoustical Consultants 2006). Extensive use of sound-absorbing material will mean that the sound is absorbed and, thus, prevented from "building up" (Cole, Blomkvist, and Ulrich 2005). When acoustic conditions are characterized by long reverberation times, echoes will cause blending and overlapping of sounds, resulting in reduced speech intelligibility. To make themselves heard, staff members then need to raise their voices, thereby compounding the noise problem even further.

Environmental strategies to reduce noise in hospitals

A combination of environmental interventions might be effective in reducing noise levels on hospital units:

- Install sound-absorbing ceiling tiles.
- Design all single-bed rooms.
- Eliminate or reduce noise sources such as overhead paging systems and staff conversations.

Research suggests that environmental interventions may be effective in reducing the noise levels in hospitals and improving the acoustical environment. Key interventions include installing high-performance sound-absorbing ceiling tiles, eliminating or reducing noise sources (for example, adopting a noiseless paging system), and providing single-bed rather than multibed rooms (Ulrich 2003).

Sound-absorbing ceiling tiles

At least three studies have shown that installing high-performance sound-absorbing ceiling tiles and panels results in reduced noise levels and perceptions of noise and impacts other outcomes such as improved speech intelligibility and reduced perceived work pressure among staff (Berens and Weigle 1996; Blomkvist et al. 2005; MacLeod et al. 2006; Hagerman et al. 2005). Though decibel levels were not greatly reduced as a result of the ceiling-tile intervention in these studies (reduction of 3 to 6 dB(A)), reverberation times and sound propagation were significantly reduced. This impacted the perception of the unit being less noisy and also improved speech intelligibility, which has implications for staff communication (Blomkvist et al. 2005; MacLeod et al. 2006).

Single-bed rooms

Single-bed rooms are probably the single most-effective strategy for reducing noise levels in patient rooms. Studies of multibed rooms in acute-care and intensive-care units have shown that most noises stem from the presence of another patient (staff talking, staff caring for other patients, equipment, visitors, patient sounds such as coughing, crying out, rattling bed rails) (Yinnon et al. 1992; Southwell and Wistow 1995; Baker 1984; Bailey and Timmons 2005). Bailey and Timmons (2005) found that noise levels increased significantly on a seven-bedded pediatric intensive-care unit when there were more people present on the unit (patients and staff). A study of multibed bays in a children's hospital concluded that noise levels were so high that consideration should be given to abolishing open bay rooms (Couper et al. 1994).

Further, patient satisfaction data provided for this report by Press Ganey (2006) unequivocally shows that patients in single-bed rooms, compared to those with a roommate, are vastly more satisfied with the "noise levels in and around your room." The satisfaction data were received from 577,787 patients in 1,363 healthcare facilities across the United States (Press Ganey 2006). Satisfaction with noise level was 15.1 percent higher on average nationally in single rooms than doubles. The higher reported satisfaction with single rooms was evident even when other patient characteristics—gender, age, length of stay, and whether it was the patient's first stay or not—were considered (Press Ganey 2006).

Eliminating or reducing noise sources

Several studies identify overhead paging systems, equipment, and loud staff conversations to be the source of loud noises on hospital units (Buelow 2001; Baker 1984; Johnson and Thornhill 2006; Kahn et al. 1998). Recommendations for reducing noise levels often include replacing overhead paging with cell phones or wireless communication devices carried by staff, removing the sources of loud noises such as ice machines from the unit, turning off equipment when not in use, conducting group conversations in an enclosed space, and educating staff about the importance of talking quietly and maintaining a quiet environment (Bailey and Timmons 2005; Buelow 2001; Baevsky, Lu, and Smithline 2000).

More healthcare facilities are incorporating wireless systems for communication. However, it is not clear whether this intervention is successful in reducing noise levels. In an emergency department, a shift from overhead paging to a personal wireless communication network was not effective in reducing noise levels (Baevsky, Lu, and Smithline 2000). However, another facility was successful in reducing the number of overhead pages (a source of noise) by more than 50 percent within two years after shifting from an interdepartmental paging system to a wireless communication network (Johnson and Thornhill 2006). Staff education programs and quiet hours (nondisturbance periods) have been somewhat successful in reducing noise levels and improving patient outcomes such as sleep, though it is not clear whether the results are sustained in the long run. (Strauch, Brandt, and Edwards-Beckett 1993; Kahn et al. 1998; Elander and Hellstrom 1995; Monsen and Edell-Gustafsson 2005).

A combination of environmental interventions (such as private rooms, sound-absorbing ceiling tiles and soft flooring) and education programs are likely to be most effective in reducing noise levels and creating better acoustic conditions for patients and staff in healthcare settings.

The Health Information Portability and Accountability Law of 1996 mandates that all individually identifiable patient information including information communicated orally be kept private. Speech privacy, indicated by a privacy index, refers to how well a private conversation can be overheard by an unintended listener. Levels of speech privacy:

- Confidential (recommended in admitting areas, areas where patients discuss their personal health, psychiatric and psychological testing rooms, hematology labs, exam rooms, etc.)
- Normal (recommended for enclosed rooms such as patient bed rooms)
- Marginal or poor
- No privacy

Speech privacy and patient confidentiality

In many hospitals and outpatient physicians' offices, patients are frequently exposed to situations where they overhear conversations with or about other patients, or worse, have their private information communicated in an open environment where it can be heard by themselves and others. Clearly, such experiences are likely to impact patient trust and their ability to discuss their health problems freely with their physicians (Barlas et al. 2001). The seriousness of the problem is underscored, for example, by a study of an emergency department where 5 percent of the patients examined in curtained spaces reported withholding portions of their private history and refused parts of their physical examination because of lack of privacy (Barlas et al. 2001). This can have serious implications for patient safety. In the last decade, concerns regarding protecting patient confidentiality have come to the fore and the Health Information Portability and Accountability Act (HIPAA) of 1996 has further elevated the importance of providing reasonable safeguards to protect the confidentiality of patient information (United States Department of Health and Human Services, Office for Civil Rights, 2003). The HIPAA law mandates that all individually identifiable patient health information be kept private and

this includes privacy of information communicated orally. Thus, it is critical that private conversations with or about a patient are not overheard.

Speech privacy refers to how well a private conversation can be overheard by an unintended listener, and the level of speech privacy achieved in a space is indicated by a privacy index (PI) (Armstrong Ceiling Systems 2003). This is expressed as a percentage and takes into account the acoustical performance of all finishes—ceiling, floors, partitions, and furniture—in the space. The commonly recognized levels of speech privacy are:

- Confidential (PI rating of 95 percent to 100 percent, conversations conducted within the space may be partially overheard but not understood outside the confines of the space)
- Normal (PI rating of 80 percent to 95 percent, conversations may be overheard but are only partially intelligible)
- Marginal or poor (PI rating of 60 percent to 80 percent, most conversations will be overheard and intelligible to unintended listeners)
- No privacy (PI rating less than 60 percent, all conversations can be fully overheard and understood) (Armstrong Ceiling Systems, 2003)

The new *Interim Sound and Vibration Guidelines for Hospitals and Healthcare Facilities* (Joint Subcommittee on Speech Privacy of the Acoustical Society of America, Technical Committees for Architectural Acoustics and Noise; Institute of Noise Control Engineering; and National Council of Acoustical Consultants 2006) recommends that normal speech privacy be provided between enclosed rooms and confidential speech privacy in admitting areas, areas where patients discuss their personal health, psychiatric and psychological testing rooms, hematology labs, exam rooms, etc.

The design of the physical environment clearly impacts patient confidentiality and speech privacy in healthcare settings, though few studies have focused on the role of unit design or architecture. Two studies compared visual and auditory privacy of emergency department patients assigned to either multibed spaces with curtain partitions or rooms with solid walls (Mlinek and Pierce 1997; Barlas et al. 2001). The studies showed that more breaches of patient confidentiality and privacy occurred in the multibed spaces with curtain partitions (Mlinek and Pierce 1997), and patients examined in such spaces were more likely to withhold information because they experienced a lack of auditory and visual privacy as compared to patients in rooms with walls (Barlas et al. 2001). While the unit design and layout often pose obvious difficulties in maintaining privacy, the carelessness of staff in communicating with patients and other staff members compounds the problem. In one study, researchers found that physicians and other hospital staff made inappropriate comments during 14 percent of public elevator trips, of which a large proportion represented patient confidentiality breaches (Ubel, Zell, and Miller 1995).

There are many spaces in healthcare settings where private conversations or information is exchanged and often easily overheard by others. Some examples of the typical difficulties posed by unit design and layout to ensuring patient confidentiality in healthcare settings include:

- Inadequate private discussion spaces in public areas such as admission areas, reception areas, and waiting rooms where private information may be discussed.
- Physical proximity between staff and visitors in admission areas and poorly designed reception areas such that telephone conversations and discussions may be overheard.
- Multioccupancy rooms where discussions with one patient can easily be overheard by other patients and their families.

- Open-plan examination areas with curtained cubicles (instead of walls), which offer little visual or auditory privacy.
- Walls in enclosed offices stop at the ceiling and do not go up all the way up to the deck allowing for sound leaks through the ceiling to adjoining enclosed spaces.
- Nonabsorbing ceilings that cause sound to reflect from one space to another as well as allows sound from one room to pass into the plenum and get transmitted down into another room.
- Inadequate private discussion rooms on patient units for physicians to conduct meetings with families.

Architectural design solutions for promoting patient privacy and confidentiality:

- Provide single-patient rooms and rooms enclosed with walls in examination and treatment areas.
- Provide private discussion areas in admitting areas as well as on the unit for private conferences with families and staff.
- Install high-performance sound-absorbing acoustical ceiling tiles to prevent sound from bouncing off from the ceiling to adjoining spaces.

Clearly, architectural design solutions could begin to address some of the obvious failings of healthcare settings in terms of preserving patient confidentiality. One design solution that is strongly supported by research is to provide single-patient rooms or rooms enclosed with walls in examination and treatment areas where patients would be required to disclose confidential health information (Barlas et al. 2001; Mlinek and Pierce 1997; Ulrich et al. 2004). Ulrich and colleagues (2004) reported patient satisfaction data from Press Ganey (2003) that clearly showed that patients in single-bed rooms, compared to those with a roommate, were consistently more satisfied with "concern for your privacy." The satisfaction data were obtained from 2,122,439 patients who received care during 2003 in 1,462 healthcare facilities (Press Ganey 2003). Satisfaction with privacy was 4.5 percent higher on average nationally in single rooms than doubles—a substantial difference considering that it can be difficult for hospitals to increase satisfaction scores by even 1 percent to 2 percent (Ulrich et al. 2004). A survey study of staff in four West Coast hospitals found that nurses overwhelmingly judged single rooms to be superior to double rooms for examining a patient (85 percent) and for collecting a patient's history (82 percent) (Chaudhury, Mahmood, and Valente 2006).

A third strategy that is sometimes recommended by ceiling systems manufacturers and others to improve speech privacy is to use sound masking, which is "the precise application of electronic background sound that blends into the environment to cover up or mask unwanted noise" (Armstrong Ceiling Systems 2003). This strategy has proven effective in open-plan commercial office environments in providing speech privacy. However, there is a lack of research demonstrating the effects and appropriateness of this intervention in healthcare settings. Given the fact that effective healthcare work requires being able to comprehend and respond to many different types of auditory stimuli—alarms, dictation, spoken communication—overhead sound systems that render speech less intelligible over short distances conceivably might negatively impact the quality and accuracy of communication

Other key recommendations for increasing speech privacy in healthcare settings include (Armstrong Ceiling Systems 2003):

- Use a high-performance acoustical ceiling to absorb sounds that would otherwise bounce off the ceiling into nearby spaces or cubicles.
- Block sound transmission between spaces by a combination of high-performance ceilings and effective wall and furniture design and layout.

that are essential in healthcare settings. The effects of sound masking on intelligibility and speech recognition errors between staff, and between staff and patient, should be carefully researched and clarified before widely incorporating such systems.

The environment clearly plays an important role in promoting patient privacy and confidentiality. There is a definite need for additional studies to examine the impact of different types of room and unit layout and finishes on privacy and confidentiality breaches in patient rooms, unit hallways, nursing stations, reception areas, and waiting rooms in healthcare settings.

Speech intelligibility

Speech intelligibility and speech privacy are very much related, though the goal is often to maximize speech intelligibility between people who need to communicate with each other (e.g., hospital staff, hospital staff and patients) and to minimize the audibility and intelligibility of their conversation (i.e., achieve speech privacy) to unintended listeners. As mentioned earlier, the issue of speech intelligibility assumes great importance in healthcare settings, more so than in other settings such as offices, because nurses and physicians are required to constantly comprehend and act on many types of auditory information in a high-paced stressful environment.

Why is speech intelligibility critical in healthcare settings?

- Staff needs to comprehend and act upon many types of auditory information.
- Speech recognition systems, which are critical for the functioning of a digital hospital, cannot interpret sound signals in a poor acoustic environments.
- Poor acoustical environments make it difficult to understand healthcare staff and patients with different languages, accents, and speech patterns.

Further, the move toward a digital hospital requires the automation of many hospital operations, and this requires use of speech-recognition systems. While normal-hearing individuals are well-adapted to detecting speech signals embedded in noise (even when signal-to-noise ratios are as low as -6 dB(A)), automated speech recognition systems require a signal-to-noise ratio of +15 dB(A) to ensure correct interpretation of the signal (Busch-Vishniac et al. 2005). A poor acoustic environment may well lead to many errors in automatic transcription of doctors' spoken notes, automatic dispensing of pharmaceuticals, etc. (Busch-Vishniac et al. 2005).

Ceiling sound-masking systems (mentioned earlier) that are effective in commercial open-plan office environments for increasing speech privacy have not been subjected to thorough research evaluation in healthcare settings such as nurses' stations where staff are constantly on the move and not likely to stay within a limited physical boundary. Research is needed to rule out the possibility that masking sounds and speech may erode intelligibility and increase risk for errors in certain healthcare situations.

As described earlier, hard reflecting surfaces cause sounds to echo and linger in spaces and have long reverberation time. This is an important factor that is linked with speech intelligibility. Research shows that installing high-performance sound-absorbing ceiling tiles is highly effective in reducing reverberation times. In the Swedish study by Blomkvist and colleagues (2005), during the period of longer reverberation time (when sound-reflecting ceiling tiles were installed on the CCU), speech intelligibility was thought to be below what was needed on the CCU. When sound-absorbing ceiling tiles were installed, reverberation times decreased and speech intelligibility improved (Blomkvist et al. 2005). Also, patients treated in the unit during the good acoustics period rated the staff attitude higher as compared to patients treated during the poor acoustics period (Hagerman et al. 2005).

Installing sound-absorbing ceiling tiles and other finishes is critical to reducing reverberation times and improving speech intelligibility in healthcare settings. In addition, single rooms with walls that go up to the ceiling should be provided in areas where private communication between patients and staff is intended to occur (such as inpatient, examination, and treatment rooms) to minimize noise intrusion from outside the room and to enhance speech privacy.

Impact of music

Music is defined as a complex of expressively organized sounds composed of some key elements: rhythm, pitch, harmony, and melody. Research shows that certain types of music induce relaxation and positive responses, which reduce activity in the neuroendocrine and sympathetic nervous systems, resulting in decreased anxiety, heart rate, respiratory rate, and increased temperature (Lai et al. 2006). Music therapy, or the therapeutic use of music to promote health and well-being in patients, has been used in different settings including oncology, maternity, postoperative, intensive care, coronary care, and pediatric (Cooke, Chaboyer, and Hiratos 2005). The music preferences of individual patients is an important factor in the effect of music on patients, as not all people are likely to prefer the same types of music due to differences in age, culture, and peer group (Lee et al. 2005). Generally, sedative music that is suitable for music intervention tends to have no accented beats, no percussive characteristics, a slow tempo, and smooth melody (Chlan 2000).

Impact of music on patients:

- Decreased anxiety and distress
- Decreased heart rate
- Decreased respiratory rate
- Higher level of satisfaction with experience

Music selection for music therapy:

- Music should ideally be selected by patients based on their preferences.
- Generally, sedative music used for music therapy tends to have no accented beats, no percussive characteristics, a slow tempo, and smooth melody.

Music therapy is the therapeutic use of music to promote health and well-being in patients. It has proven highly effective in different settings including oncology, maternity, postoperative, intensive care, coronary care, and pediatric.

Studies have shown that listening to music is beneficial to patients undergoing painful procedures. For example, studies that examined the effect of listening to music among mechanically ventilated patients in an intensive-care unit found that relaxing music reduces subjective states of anxiety and emotional disturbance as well as physiological outcomes such as heart rate and respiratory rate (Chlan et al. 2001; Chlan 2000; Lee et al. 2005). In one study, patients were randomly assigned to either listen to thirty minutes of music (patients selected from given music options) through headphones or a rest period with no music (Lee et al. 2005). The heart rate, respiratory rate, systolic blood pressure, and diastolic blood pressure reduced among the patients who underwent the music intervention while there was no difference in physiological measures in patients in the control group (no music) (Lee et al. 2005).

A similar study conducted among women undergoing Caesarean delivery found that the women who listened to music during the delivery had lower anxiety and a higher level of satisfaction regarding the experience (Chang and Chen 2005). Other studies have found that listening to music reduces anxiety among mothers providing care to preterm infants in the NICU (Lai et al. 2006) and reduces acute postoperative confusion and delirium among elderly patients undergoing elective hip and knee surgery (McCaffrey and Locsin 2004).

Research also shows that listening to individualized music (based on personal preferences) is effective in decreasing behavioral problems and agitation among dementia patients (Goodall and Etters 2005). Studies conducted among children have found that recorded lullabies were an effective distraction in reducing overall distress in children receiving routine immunizations (Malone 1996; Megel, Houser, and Gleaves 1998).

Cooke and colleagues (2005) reviewed twelve experimental studies that examined the impact of music on reducing anxiety and other outcomes among patients while waiting in ambulatory-care settings such as in a day surgery. In all studies, patients who listened to music experienced less anxiety. The authors conclude that music as a simple and cost-effective intervention to reduce anxiety experienced in limited time periods has strong positive implications for clinical practices where patients wait before undergoing invasive investigations, procedures, or surgery (Cooke, Chaboyer, and Hiratos 2005).

There is strong support for music therapy as an effective intervention for patients undergoing painful procedures or experiencing anxiety. In the studies examined here, patients either listened to music through headphones or from a nearby cassette player. Few studies were found that examined the effect of ambient music on patient anxiety or other outcomes. Also, no studies were found that examined the impact of music on staff and families. These are areas where future research is needed.

Summary

Sounds impacts patients and staff in many different ways. Unwanted sound or noise is a major problem in hospitals the world over. High noise levels negatively impact patient and staff health and well-being and may slow the process of healing among patients. On the other hand, certain types of music help to reduce anxiety and distress among patients. Poorly designed environments can result in private conversations between patients and staff or between staff members being overheard by unintended listeners, resulting in unacceptable breaches of confidentiality. At the same time, a poor acoustical environment impedes effective communication by rendering speech and auditory signals less intelligible. This has serious implications for patient safety.

Much evidence shows that improving the acoustical environment in hospitals by carefully considering design factors can go a long way toward reducing noise, improving speech intelligibility, as well as increasing patient confidentiality. Key design considerations include:

- Providing single-patient rooms— compared to multibed rooms, private rooms are less noisy, are perceived by patients as being more private, and permit more effective and confidential communication between staff and patients.
- Installing high-performance sound-absorbing acoustical ceiling tiles results in shorter reverberation times, reduced sound propagation, and improved speech intelligibility. Also, this design measure increases speech privacy as less sound travels into adjoining spaces.
- Removing or reducing loud noise sources on hospital units and educating staff about the impact of noise on patients as well as themselves is effective in reducing noise levels.
- Providing patient examination rooms and treatment areas with walls that extend fully to the support ceiling will prevent voice and noise carrying through ceilings.

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Notes

[i] Noise levels are measured using the A-weighted sound level, which represents the filtering of sound that replicates the human hearing response. This is the most commonly used descriptor to quantify the relative loudness of various types of sounds with similar or differing frequency characteristics.