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Investigation to Determine Whether the Built Environment Affects Patients' Medical Outcomes

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INTRODUCTION

In a dark place the sick indulge themselves too much in various fancies, and are harassed by imaginings devised in an alienated mind, since no external phenomena can fall on the senses; but in a bright place they are prevented from being wholly in their own fancies, which are rather weakened by external phenomena. – Asclepiades of Bithynia, ca. 50 B.C.¹

Second only to fresh air ... I should be inclined to rank light in importance for the sick. Direct sunlight, not only daylight, is necessary for speedy recovery ... I mention from experience, as quite perceptible in promoting recovery, the being able to see out of a window, instead of looking against a dead wall; the bright colours of flowers; the being able to read in bed by the light of the window close to the bed-head. It is generally said the effect is upon the mind. Perhaps so, but it is not less so upon the body on that account– Florence Nightingale, 1860²

Throughout the long history of Western medicine, sensitive caregivers have believed that the physical environment in which therapy is provided may modify that therapy's effect on patients.

In pre-Christian Rome, the influential physician Asclepiades of Bithynia argued against the prevailing practice of sequestering the sick in shadowy rooms – itself based on the notion that darkness is soothing and contributes to patients' peace of mind.

From her experiences ministering to the wounded in the Crimean War, Florence Nightingale strongly advised the British government that the convalescence of patients would be hastened if hospitals were built to afford them fresh air, sunlight, calm and quiet, views of nature, and a setting filled with “beautiful objects ... especially of brilliancy of colour.”³

Surprisingly, given the ancient and honorable lineage of this hypothesis, little modern scientific research has been conducted to test the premise that aspects of the healthcare environment (other than cleanliness) have effects on therapeutic outcomes. We know as much from a major review of the medical literature performed in 1995 and updated in 1997 and 1998 by Haya R. Rubin, M.D., Ph.D., and colleagues from Quality of Care Research at The Johns Hopkins University, in Baltimore, conducted under the auspices of The Center for Health Design.

After culling more than 78,761 potentially relevant titles from medical databases, the research team identified only 1,219 articles that appeared to describe investigations into the impact of environmental elements on health outcomes.

They had cast their net broadly, too. They looked for any study in which scientists had attempted to gauge the relationship between health outcomes and the physical environment. A wide range of diverse aspects of the physical environment were addressed, including such topics as room size, room privacy, controllability of the environment by the patient, music, lighting, type of window view, humidity, and temperature.

Nevertheless, only a few dozen reports in the medical literature since 1966 actually turned out to contain data that relate a particular design feature to a specific clinical outcome for a particular study population. The 84 studies judged relevant are outlined in greater detail in Appendix B of this report.

Unfortunately, moreover, the methodological rigor of this small volume of research varied enormously. Fewer than a third of the studies, for example, were randomized, controlled trials – the most reliable scientific technique for assessing the effects of a medical intervention or a treatment variable.

One such, as an illustration, tested the impact of artificial light on babies in hospital nurseries by randomly assigning a sample of 50 newborns to cribs under blue light (the highest-intensity visible wavelength), while another matched sample of 50 babies were placed in cribs under red light (the lowest-intensity visible wavelength). The researchers observed and reported in 1992 that the babies subjected to blue light were more wakeful, slept more often but more briefly, and had more irregular patterns of sleep. Yet for all its strength of

research design, a single study of 100 babies – all healthy and sharing a single ethnic background – leaves open the question of whether the same results would pertain among babies of other ethnicities, or among sick or premature babies, for whom regular, sound sleep may be an important factor if they are to thrive.

Another small subset of the studies were experimental trials with paired data, or observational studies with paired data, both of which are also considered by scientists to be reasonable constructs for drawing relatively reliable research conclusions when well crafted.

An instance of the former involved a 1975 study of 19 premature infants whose incubators were first set at high humidity and then at low humidity. Eight of the infants experienced severe breathing problems, and the episodes of apnea occurred in significantly greater proportion when the humidity was kept low. Here again, however, a single study of a very small group of subjects is not sufficient to support broad generalizations even when the method is sound. Similarly, a 1992 observational study of nearly 14,000 patients in a state mental hospital indicated that when rock or rap music was played in a common area, the patients exhibited more incidents of “inappropriate behavior” than when country or “easy listening” music was played. The unusually large cohort of subjects involved lends weight to the finding, but the study did not control for the various rhythms or lyrics of the music that could possibly be provocative factors.

Indeed, none of the investigations into the effects of environmental features on patient outcomes undertaken in the last 30 years is immune to criticism. The majority are significantly flawed. To be sure, few if any scientific studies produce incontrovertible evidence. Unshakable judgments based on one or two trials, no matter how large or tightly controlled to eliminate chance, confounding factors, and experimenter bias, are rarely if ever drawn by circumspect scientists. And analysis of this body of research is at least suggestive that a cause-effect relationship exists between some health-care environmental factors and therapeutic outcomes for some types of patients.

Thus, one conclusion from the research team’s initial assessment is that research in this field holds promise, but that more and better studies are vitally needed. The effort would appear to be justified if nothing else on the evidence of the best of the studies surveyed, a high proportion of which did find significant associations between the environmental variable investigated and a health outcome.

In an era of intense concern over the rising costs of medical care, improving therapeutic results through the most efficient allocation of finite resources has become the touchstone of healthcare practice and processes. If, in fact, the very environment in which patients receive treatment has a significant influence on their physical

responsiveness and prognosis, it is important to determine which elements can promote more satisfactory outcomes under what circumstances. Healthcare facilities can then be designed to take advantage of such knowledge.

Continued expenditure for structures whose layout, ambience, and appurtenances are informed by guess, fad, or the personal preferences of designers, administrators, healthcare professionals, or even patients themselves – absent solid efforts to square aesthetic leanings and unsupported theories with outcomes data to the extent scientifically possible – is a frivolity we can no longer afford.

This report builds on an analysis of past research to suggest an agenda for further inquiry into the effects of healthcare settings on patient outcomes. It offers a general conceptual model of the ways in which environmental features may influence patients' health, as a guide to the formulation of future research protocols. And it provides four illustrative design applications of how credible scientific evidence might be incorporated into the design of specific aspects of the physical environment to improve therapeutic results.

The research team also outlines a complete research program aimed at validating or discrediting hypotheses about the degree to which the efficacy of healthcare can be enhanced or diminished by key aspects of the designed environment.

Finally, as recommended in the first element of this agenda, the research team conducted focus groups to assist in the identification of patient populations in whom hypotheses about the influences of the healthcare environment might be proven or disproven.

Sponsored and coordinated by The Center for Health Design, with funding from outside sources and augmented by the ongoing investigations of independent scientists, the completion of the major research agenda outlined in this report might at last bring to reality a future foreseen a quarter of a century ago by another visionary healthcare observer, noted hospital architect E. Todd Wheeler:

Eventually scientific findings will go beyond subjective responses The doctor will then know how to write a prescription for environment even as he now does for drugs, and technology will modify and maintain it to his prescription, applying all beneficial variables, including ... temperature; air content of solids, liquids and gases; air pressure and movement; light in all its aspects, including movement and color; other forms of radiation; ionization; size and shape of enclosure; physical movement of the enclosure; pattern and texture of materials; sound, both generated and absorbed; and the physical form.⁴

¹ From Gumpert, Christian Gottlieb, *Fragments from Asclepiades of Bithynia*, Weimar, 1794, in Green, Robert M., *Asclepiades: His Life and Writings* (New Haven: Elizabeth Licht, 1955).

² Nightingale, Florence, *Notes on Nursing: What It Is and What It Is Not* (London: Harrison, 1960).

³ *ibid.*

⁴ Wheeler, E. Todd, *Hospital Modernization and Expansion* (New York: McGraw-Hill, 1971).

PREFACE

Background and Rationale — Improving Patient Outcomes Through Design of the Healthcare Environment

Wise use of healthcare resources to improve patient health and wellbeing, promote efficiency, reduce employee turnover, and avoid wasteful spending dictates a careful examination of the ways in which such an encompassing factor as the built environment can affect patients' health outcomes. If it is, in fact, an important contributor to healthcare effectiveness, it is easily manipulable. Without knowing which, if any, aspects of the physical setting make a difference, however, health facility design decisions will continue to be made on the basis of untested propositions. Money could be saved and a greater payback realized if design decisions were grounded in scientifically valid information.

These were the premises upon which The Center for Health Design contracted in September 1995 with Quality of Care Research at The Johns Hopkins University to develop a concept paper for a research master plan that would address whether and in what ways patients' clinical outcomes might be improved through designed elements of the healthcare environment. Three tasks were included in the contract: (1) to review the literature to find out what is known about the effect of the healthcare environmental design on patient health outcomes, (2) to suggest design applications based on selected findings in the literature, and (3) based on the literature review, to make initial recommendations for developing a research agenda in this area for the next 10 or more years.

Background and Rationale

A revised report was published in November 1997 with an expanded literature review, the addition of 19 studies to Appendix B, and a new application on air quality.

In 1998, The Center for Health Design asked the Johns Hopkins investigators to continue to update the literature review and to conduct focus groups to choose a patient population for experimental study of how the healthcare environment may improve patient outcomes. This Status Report includes an expanded literature review including 17 new studies in Appendix B, a new design application on sunlight and daylight, and reports of the focus groups conducted to help choose subjects for study of the effects of the health-care environment on medical outcomes.

1. THE STATE OF OUR KNOWLEDGE

The first step was to review the literature to find out what is already known.

Framing the Search

The healthcare environment was taken to include anything that can affect a patient through the senses. In a brainstorming session with staff from The Center for Health Design, a list of environmental design features was compiled. The Center's Healthcare Design Research Committee then reviewed, amplified, and refined the list, resulting in the selection of elements included in the search keywords in Table 1 (see PDF version). More formal studies toward the definition of the healthcare environment would be helpful in tailoring future research agendas.

In 1995, the computerized literature search used the National Library of Medicine Health Planning and Administration and Medline electronic databases to find any articles that contained data about how one or more of the listed features of the healthcare environment were related to any clinical patient outcome listed in Table 2. In September 1997, the Health Star and Medline databases were used to expand the original search. Further details of the 1997 search strategy are contained in Appendix A. Studies that addressed costs of healthcare but not patient outcomes were excluded from the literature survey. Studies of patients' and clinicians' preferences for certain environmental features were judged to lie outside the scope of the project as well.

Patient Outcomes Included in Literature Search

1. Physical, anatomic, or physiologic health
2. Diagnoses or diseases
3. Adverse events or complications
4. Patients' reports or evaluations of aspects of their health: Symptoms Functional status Well-being
5. Patient evaluations of healthcare environment

Several studies were found that investigated the effects of the built environment on employee function or behavior. While staff morale, efficiency, and job performance certainly may contribute to patient outcomes, demonstration of the nature and degree of the linkage under specific circumstances requires additional work that lies outside the scope of the project; therefore, such studies were excluded.

The Yield

Table 3 (see PDF version) indicates results and yield of the search completed in 1998.

Results

As of September 1998, the Johns Hopkins reviewers had examined 78,761 articles for possible inclusion, as listed in Table 3. Thus far, the search revealed only 84 articles published in the medical and design literature in the last 30 years that contain relevant data. These studies are abstracted and critiqued in Appendix B (see PDF version). Seventy-four of the studies (88 percent) demonstrated that some healthcare environmental feature was related to at least one patient outcome parameter. Those features that were found by at least one study to influence at least one health outcome are:

- Intensity of artificial lighting
- Placement of ultraviolet lights
- Temperature (this and the previous feature were studied in premature infants)
- Humidity (in premature infants, geriatric patients, and mechanically ventilated patients)
- Ventilation system contaminants (in intensive care, ambulatory surgery, leukemia and bone marrow transplant patients)
- Temperature of respired air (in mechanically ventilated patients)
- Tapes of music, therapeutic suggestion, and sound simulation (tapes were studied in patients undergoing coronary artery bypass surgery, gynecologic surgery, emergency laceration repair, or arthroscopic surgery; in children undergoing dental cavity preparation; and in newborns)
- Type of ambient music (in psychiatric patients)
- Noise levels (in intensive care and postoperative patients)
- Natural window views (in patients after cholecystectomy and in intensive care after major surgery; and for neonates)
- Room exposure to sunlight (in depressed patients)
- Exposure to outdoor sunlight (elderly patients in geriatric facility)
- Amount, layout, and decor of spaces for social interaction, staff use, those with disabilities or wheelchairs, and outdoor areas (in psychiatric and substance abuse treatment facility patients)
- Furniture placement (in psychiatric and rehabilitation patients)
- Room carpeting (in elderly patients)
- Bedside computers (in geriatric medical and surgical patients)
- Newly built versus refurbished ward (in geriatric patients)

- Bed enclosures (in burn patients)
- Privacy/openness of room or ward (in acute medical patients and patients undergoing cataract surgery)

Critique of Methods

Many of the research studies had significant methodological flaws that weakened the validity of their conclusions.

First, some study designs are better than others for deciding whether an environmental feature matters. Table 4 (see PDF version) describes the most common study designs encountered and comments on their strengths and weaknesses. Appendix B classifies each article according to its study design.

There were 23 randomized controlled trials. This is the best way of organizing a scientific investigation. There were also experimental studies with paired data, another strong study design. Most of these involved premature infants who were examined under different incubator conditions.

The preponderance of articles described observational studies; that is, groups of patients who had been located in different environments in the course of their routine care were compared. In several studies, the groups of patients were observed in different units or hospitals. This raises the concern that unspecified and unmeasured differences between the two study sites were in fact responsible for the differences reported. In these studies, most of the researchers also neglected to measure important patient characteristics that could have caused different outcomes in different environments.

A few observational studies used paired data where patients serve as their own controls. This is a stronger study design because it eliminates the concern that differences among the patients in different groups are responsible for the variance, rather than the environmental factor or factors under investigation.

Another methodological problem clouding the findings in many of the extant studies is that the research personnel were not “blinded.” When collecting data, study staff members knew which type of environment patients were in. Thus, they could have been influenced unconsciously when judging or measuring an outcome.

Few of the studies discussed how the patients included in the study may or may not resemble other patients to whom a reader might want to generalize the results. Some studies failed to include even a minimal description of the patients who had participated. Thus, it is uncertain whether the finding would apply as well to the specific types of patients a reader wants to know about.

Few studies included tests of the reproducibility (also called reliability) or accuracy (validity) of the outcome measures used. Many of the studies with better methods were studies of varying incubator conditions for premature infants; there were fewer good studies of adults or children with other medical conditions.

Incidentally, the additional extant studies identified during the expansion of the initial literature review, and added to the 1996 report's list in Appendix B, were conducted with a similar level of rigor and quality to those previously identified.

Are Investigators Finding What They're Looking For?

Methodological flaws may influence the likelihood that a study would find a relationship between an environmental feature and a patient outcome. This phenomenon permeates the history of medical research, in which loosely constructed experiments tend to give the answer sought by the investigators. Of the studies with weaker study designs, 37 of 39, or 95 percent, concluded that the environmental feature under investigation affected at least one health outcome measure. However, of the 45 studies with relatively stronger research methods – that is, randomized trials, experimental trials with paired data, or observational studies with paired data – 37, or 82 percent, also found positive correlations. This difference between the proportions of studies with better and worse methods that found measurable associations between the environment and a clinical outcome was not of statistical significance ($p > 0.075$). A very high proportion of studies characterized by strong methodology also found such associations. Therefore, methodological flaws probably are not responsible for the preponderance of published research studies that have found associations between environmental features and clinical outcomes.

The analysis of the body of existing research leads to three important conclusions. First, because the large majority of published studies characterized by better research designs have found that an environmental feature is related to health outcome, at least in the short term, improvements in outcomes may indeed be available through design interventions guided by sound scientific inquiry.

Conclusions

Second, studies that contain data about the effect of the environment on health outcomes are surprisingly scarce. The need for a broadened research effort in this area is striking. Many aspects of the healthcare setting and many patient populations have never been investigated.

Third, many published studies have significant methodological flaws that render their conclusions suspect or cast doubt on the generalizability of their findings. Future research into the effects of the healthcare environment on patient outcomes should be more carefully designed and performed with greater methodological rigor. In particular, researchers should make strong efforts to ensure that groups of patients being compared under varied environmental conditions do not differ in other ways that may skew the results.

2. A MODEL ENVIRONMENT & OUTCOMES

A working theory of what affects patients' health outcomes is necessary for interpreting the results of the research on the influence of the physical environment. Such a hypothetical grounding is also helpful when considering which studies might contribute most in the future.

One model includes the following factors and their interactions that determine clinical outcomes for patients: (1) the medical treatment provided, including technical and interpersonal aspects; (2) patients' personal characteristics, such as age, sex, and relevant physical, physiological, and emotional traits: For example, a patient in good physical shape may recover more quickly from surgery than one who is out of shape; (3) illness factors, such as stage or etiology: For example, all else being equal, a patient with metastatic cancer is likely to have a worse outcome than one with an asthma attack; and (4) features of the physical environment.

The Environment-Outcome Interface

With this model in mind, how can aspects of the designed environment interrelate with medical care, illness, and patients' attributes to influence patients' health? The healthcare setting may either magnify or diminish the effects of medical intervention, personal characteristics, and causes of illness to influence the ultimate therapeutic outcome. Figure 1 (see PDF version) illustrates this concept schematically.

- The designed environment can support or hinder caregiver actions and medical interventions, making it harder or easier for clinicians to do their jobs, and facilitating helpful actions or preventing harmful ones. For example, the call bell enables patients to summon nurses or doctors to the bedside when emergency assistance is needed, and carpeting reduces the hubbub of clinical personnel going about their business.
- The designed environment may impair or strengthen patients' health status and personal characteristics, by alleviating or exacerbating already existing conditions and by opposing patients' natural strengths. For example, loss of sleep due to noise may prolong recovery time after a procedure more for those who were in a worse state, with more preexisting health problems, than for those who were comparatively well to begin with. Conversely, equipment designed to make activities of daily living possible and easy –

a bedside commode or a speaker phone, as examples – may prevent dysfunction for some patients with physical impairments who might otherwise be unable to reach and use them.

- The designed environment can protect patients from or expose them to causes of illness. For example, excessive noise may alter sleeping patterns, reduce REM sleep, and thereby cause irritability and dysfunction; patients treated in the hospital may be spared debilitating or even deadly nosocomial infections by the circulation of ultraclean air.
- This conceptual model makes it clear that when health outcomes for patients treated in different environmental conditions are compared, researchers must make certain that the patients in each of the study groups are similar in their burdens of illness and in other characteristics that affect their health.

It is also apparent from the model that investigators must make sure that the patients being compared have received the same clinical treatment in environments that were similar in every way in addition to the presence or absence of the feature being studied. Especially in “natural history” studies, in which the environment is observed but not manipulated, methodological problems arise because investigators are unable to control all the variables that affect patients’ health.

Indeed, the model highlights the barriers that exist in attempting to isolate specific environmental features for rigorous scientific study. The healthcare setting is complex. It is hard to change only one feature without changing others. The amount of knowledge that can be gained through clinical research is thus limited. Unfortunately, there are likely to be important environmental effects on health outcomes that will never be amenable to isolation and demonstration. Therefore, many of the decisions about the design of healthcare facilities will necessarily continue to rely on best guesses.

Nevertheless, the literature review confirms that many features could be studied more rigorously than they have been until now.

Suggested Applications: Quiet, Music, and Air Quality

To illustrate how the design of the physical environment might be based on scientific evidence of what promotes better patient outcomes, the Johns Hopkins team focused on studies of the auditory environment and air quality that were characterized by relatively strong research methods. Translated into design principles, the study conclusions can be applied pragmatically to representative health-care settings.

This expanded Status Report includes a new application on air quality. This application was selected because there were several high-quality studies indicating that contaminated air causes hospital-acquired infections. Better design of ventilation systems in health-care facilities thus may improve patient outcomes by preventing such infections.

1. Quiet in the CCU

The Study: Topf M, Davis V. Critical care noise and rapid eye movement (REM) sleep. *Heart and Lung* 1993; 22 (3): 252–258.

- *Research Question:* Does CCU noise affect REM sleep?
- *Methods:* Seventy healthy women were randomly assigned to sleep in a sleep lab under quiet conditions or listening to an audiotape recording of CCU sounds. Ten measures of REM sleep were assessed, including REM activity and duration during the first and second halves of the night and throughout the night, and the interval between first and second REM cycles.
- *Findings:* Women exposed to CCU noise had less REM activity, shorter REM durations, and longer intervals between REM cycles.
- *Limitations:* Use of volunteers in a lab means we cannot be sure that the results apply to patients in the CCU, although less REM sleep for critically ill patients could reasonably be assumed to be more problematic than for healthy volunteers. The relationship of REM sleep in the CCU to longer-term outcomes is unknown, although more sleep is a desirable short-term outcome for patients with myocardial infarction.
- *Conclusion:* CCU noise may suppress REM sleep. The Design Principle: Dampen ambient sound in critical care units to the extent possible.

Sample Design Application: Figure 2 (see PDF version) illustrates a critical care room incorporating design strategies to promote quiet, including:

1. Ceiling utilizes specialty acoustic tile with a Noise Reduction Coefficient (NRC) in the range of 0.85 to 1.0.
2. All chairs are upholstered with sound-absorbent fabric.
3. Flooring in all areas consists of acoustical resilient sheet vinyl with sound-deadening properties.
4. Wall panels are sound-absorbent.
5. Noise-cancellation headphones are provided.

2. Music during Minor Surgery

Three studies are abstracted below that describe how music may affect medical outcomes.

The Study: Menegazzi JJ, Paris P, Kersteen C, et al. A randomized controlled trial of the use of music during laceration repair. *Ann Emerg Med* 1991; 20: 348–350

- *Research Question:* Does music chosen by patients and played through a headset change their vital signs or reduce their pain or anxiety during laceration repair in the emergency room?
- *Methods:* Thirty-eight emergency patients who underwent laceration repair with local anesthesia at the University of Pittsburgh teaching hospital were randomized to receive headset music or not to receive music during the repair. Patients in the music group chose from 50 available styles and artists and controlled the volume themselves. Investigators monitored heart rate, blood pressure, respirations before and after the repair, and obtained pain ratings and a state of anxiety scale after the procedure. The group that heard music was asked to rate how beneficial the music was as well.
- *Findings:* Patients who listened to headset music that they chose had less pain and similar anxiety levels to those in the control group. Of those who heard music, 89 percent thought it was very beneficial and 100 percent said they would use it again if it were offered.
- *Limitations:* A small study at one hospital can give spurious results, so it should be repeated at other hospitals to confirm the findings.
- *Conclusion:* Patient-selected headset music during laceration repair in the emergency room helps reduce pain.

The Study: Moss VA. Music and the surgical patient. AORN Journal 1988; 48(1): 64–69.

- *Research Question:* Does music affect anxiety of patients undergoing elective arthroscopic surgery under general anesthesia?
- *Methods:* Seventeen patients from one orthopedic practice who were to undergo arthroscopy with possible closed meniscectomy, femoral or patellar chondrectomy, or lateral release were assigned to be exposed to no music or to sedative music during the perioperative period. A written State-Trait Anxiety Inventory (STAI) was administered preoperatively and postoperatively.
- *Findings:* Patients exposed to music showed a significant decrease in anxiety based on comparison of their preoperative and postoperative scores, whereas control patients' scores showed no difference.
- *Limitations:* The sample size was small, and it is unclear whether patients were assigned to music randomly by the investigators. This creates the possibility of bias.
- *Conclusion:* Perioperative music for arthroscopic surgery may reduce patients' anxiety.

The Study: Parkin SF. The effect of ambient music upon the reactions of children undergoing dental treatment. ASDC J Dent Child, 1981; 48(6): 430–432.

- *Research Question:* Does ambient music during dental cavity preparation affect children's anxiety levels during the procedure?
- *Methods:* Twenty-five children scheduled for two different visits to the Children's Dentistry Department of a dental hospital for cavity preparation were assigned to be exposed to ambient music on one visit and not to receive music on one visit. Children ranged in age from 7 to 14 years old. Children were recorded on silent videotape for a period of 60 seconds at each visit. Four independent observers blinded to the presence or absence of music graded the child's anxiety using a visual analogue scale.

- Results: Patients were graded as less anxious during the visit at which they heard music.
- Limitations: Investigators themselves raised, but could not answer, the question of whether it was the music or the novelty of the music that created the effect.
- Conclusion: Ambient music may reduce children's anxiety during cavity preparation.
- The Design Principle: Provide a way for patients undergoing minor surgery to listen to music, preferably of their choice, during the procedure.

Sample Design Application: Figure 3 (see PDF version) demonstrates an operating room designed to provide music during minor surgery, including the following features:

1. Speakers are installed in the ceiling.
2. Headphones for playback of personally selected music are available for use at the discretion of the patient and/or surgical personnel.
3. Speakers are attached to the underside of the operating table.
4. TheraSound™ Body Mat on the operating table provides the patient a full-body experience of sound and vibrational resonance before and after the procedure or throughout at the surgeon's discretion.

3. Air Quality

The seven studies below describe how air quality may affect medical outcomes.

The Study: Fridkin SK, Kremer FB, Bland LA, Padhye A, McNeil MM, Jarvis WR. Acremonium kiliense endophthalmitis that occurred after cataract extraction in an ambulatory surgical center and was traced to an environmental reservoir. *Clinical Infectious Diseases* 1996; 22: 222–7.

- *Research Question:* Did the contamination of the high-efficiency particulate air filter (HEPA) in the heating, ventilation, and air-conditioning system lead to the development of postoperative endophthalmitis caused by Acremonium kiliense – a fungus occasionally associated with posttraumatic keratitis?
- *Methods:* Two hundred and sixteen patients of an ambulatory surgical center undergoing cataract extraction with intraocular lens implementation were analyzed in a matched case and control study comparing procedures on the first operative day of the week versus other days and procedures before 8:45 AM versus after. An environmental evaluation was also conducted.
- *Findings:* Case patients all had surgery on the first operative day of the week or had surgery significantly sooner after the operating room opened than did controls (a median starting point of 46 vs. 150 minutes after opening [range, 30–72 vs. 30–255 minutes]; $p=.03$). The environmental evaluation revealed that the ventilation system was turned on 5–30 minutes before procedures on the first operative day of the week, and the air was filtered before but not after humidification. Cultures of the humidifier water in the ventilation system yielded *A. kiliense* phenotypically identical to isolates from case patients.

- Limitations: There is a possibility that case and control patients also differed in other important aspects, as this is not reported.
- Conclusions: An environmental reservoir of *A. kiliense* apparently caused infection of the patients when the ventilation system was switched on each week.

The Study: Loo GV, Bertrand C, Dixon C, Vitye D, Eng B, De Salis B, McLean APH, Brox A, Robson HG. Control of construction-associated nosocomial aspergillosis in an antiquated hematology unit. *Infect Control Hosp Epidemiol* 1996; June 17(6): 360-364.

- *Research Question:* Did an environmental control program help to control a construction-related outbreak of invasive aspergillosis in patients with leukemia or bone marrow transplants?
- *Methods:* From January 1988 to September 1993, 141 neutropenic patients with leukemia or bone marrow transplants were admitted into the hematology and oncology unit. These patients were divided into three groups: pre-construction of addition to the hospital, during construction, and during construction after institution of infection-control measures. These measures included HEPA-filter air purifier units and application of copper-8quinolinolate formulation. Air and surface samplings were performed on three occasions corresponding to the three time periods above. Incidence densities were calculated and compared to the preconstruction baseline rate of nosocomial aspergillosis.
- *Findings:* Thirty-six cases were diagnosed. The incidence density in the preconstruction period was 3.18 per 1,000 days at risk. During construction activity the ID increased to 9.88 per 1,000 days at risk. After implementation of infection-control measures, the ID decreased to 2.91 per 1,000 days at risk.
- *Limitations:* Different stages in construction may have affected the results (i.e., demolition vs. new construction). A study at one hospital may not be generalizable.
- *Conclusion:* An environmental control strategy probably assisted in preventing invasive aspergillosis due to construction.

The Study: Cotterill S, Evans R, Fraise AP. An unusual source for an outbreak of methicillin-resistant *Staphylococcus aureus* on an intensive therapy unit. *J of Hospital Infection* 1996; 32: 207-216.

- *Research Question:* Did the exhaust ducting of an isolation room ventilation system being next to an open window of the Intensive Treatment Unit (ITU) lead to an outbreak of *Staphylococcus aureus* in patients being nursed in the bed directly below the window?
- *Methods:* Of 100 patients admitted to the ITU during the period of October 1993 to February 1994, 6 patients were found positive for methicillin-resistant *Staphylococcus aureus* (MRSA) strains with the same antibiogram and phase type. Investigation of the environment included microbiological samplings and assessment of the ventilation system of the isolation room. The side room ventilation system could not be sampled due to constant occupation of the room.
- *Findings:* All case patients had initially been nursed in the same bed. Inspection of the outside of the building revealed that the exhaust grille of the isolation room was in close proximity to an open window directly above bed 3. It was also determined that a switch controlling air flow in the isolation room was

broken and that the room was under positive pressure. After fixing the switch and sealing the window, there were no further cases of colonization by the same strain of MRSA.

- Limitations: Although accumulation of dust containing MRSA within the ITU ventilation ducts was documented, the failure to show conclusively that the ventilation system was infected makes the findings somewhat less conclusive.
- Conclusion: The proximity of the exhaust ducting from a side isolation room to the open window above bed 3 probably led to the outbreak of MRSA associated with that bed.

The Design Principle: By improving the purity of indoor air, it is possible to reduce the risk of infection of immunocompromised individuals.

Sample Design Application:

1. Replace perforated ceiling tiles with nonporous material.
2. Install high-efficiency particulate air (HEPA)-filter air purifiers for all incoming air supply.
3. Apply copper-8-quinolinolate-formulation.
4. Seal all windows completely to prevent infiltration.
5. Install timers that can automatically turn on the ventilation system a minimum of two hours before invasive procedures begin.
6. Identify location of all exhaust vents and relocate any that could contaminate the air supply of immunocompromised individuals.
7. Minimize horizontal, dust-collecting surfaces.

The Study: Abzug MJ, Gardner S, Glode MP, et al. Heliport-associated nosocomial mucormycoses [letter]. *Infection Control & Hospital Epidemiology* 1992; 13(6): 325–326

- *Research Question:* Were three isolated cases of nosocomial mucormycosis in the oncology unit caused by increased use of a heliport located near the ventilation system intake ducts?
- *Methods:* After three cases of mucormycosis were diagnosed in a pediatric teaching hospital between March and September 1985, microbiology, pathology, and nosocomial infection records from 1978 to 1985 were reviewed. The ventilation pathway for the oncology unit was traced via hospital blueprints to intake vents in close proximity to the heliport. Thirty room air samples were taken from nine patient rooms in the oncology unit over five different days during a three-month period. Eleven air samples from above the false ceiling panels in three patient rooms were also taken, along with samples of the gravel that covered the roof near the helipad and cultures of the filters inside the intake vents for the ventilation system.
- *Findings:* There were no cases of mucormycosis observed between 1978 and 1985 and three cases in 1985. Review of heliport use determined that the three infections had occurred after periods of increased heliport utilization. Upon taking off or landing, the helicopter regularly blew gravel into the intake vents at

speeds upwards of 70 mph. The gravel samples from under the helipad and the filters in the intake vents were found to be contaminated with zygomycetes. The air samples from the patient rooms were also found to be contaminated. After installing high-efficiency particulate air (HEPA) filters in the oncology patient rooms and replacing the gravel under the helipad with an impervious neoprene roofing material, no further cases of mucormycosis were reported as of 1991.

- Limitations: Because this was an observational study, other possible sources of temporary infection such as minor construction cannot be ruled out.
- Conclusion: The three isolated cases of mucormycosis were most likely caused by ventilation intake ducts near contaminated gravel and increased heliport use, which resulted in gravel blown into the ducts and contamination of the patient rooms.

The Study: deSilva MI, Rissing JP. Postoperative wound infections following cardiac surgery: significance of contaminated cases performed in the preceding 48 hours. *Infection Control* 1984; 5(8): 371–377

- *Research Question:* Was a marked increase (from 1% to 9%) in postoperative wound infections following cardiac surgery the result of a defective air-handling system?
- *Methods:* Investigations were conducted of patients, operating room practices, ventilation and air-conditioning in the operating room. Microbiological cultures of the operating room environment and equipment were also taken. Relevant information was obtained from medical records, infection control surveillance records, the operating room log book, personnel interviews, and direct observation. A detailed study of the air-handling system for the entire surgical suite was also undertaken.
- *Findings:* The study of the air-handling system disclosed several problems:
 1. Although federal standards required 15 air changes per hour, the exchange rate was actually closer to 3 or 4 changes per hour.
 2. The ventilation system used filters with efficiencies more suited to residential areas, but less than adequate for an operating room.
 3. A “thermal wheel” designed to recapture cooling or heating potential from exhausted air was not functioning, making it difficult to maintain the proper relative humidity near 50–55%.
 4. Stagnant water condensed from the cooling coils in the intake path presented a potential path of bacterial aerosol contamination.
 5. There was inadequate positive pressure of operating room air due to high traffic during surgical procedures and open doors.
 6. Relatively arbitrary changes in relative humidity occurred when changes were made to the room temperature to augment raising and lowering of patient body temperatures.

In addition, it was found that four of the seven infected patients had been operated on within 48 hours of a contaminated surgery in the same operating room. In all, a statistically significant 29% of open-heart surgeries (4 of 14) performed within 48 hours of a contaminated surgery resulted in a wound infection (p

= .023). After changes to the air-handling system including improved filtration, maintenance of constant temperature and humidity, and elimination of the stagnant water under cooling coils, the infection rate fell to less than 1%.

- **Limitations:** Other factors could have contributed to the rise and subsequent fall in the infection rate. These factors may have included changes in operating room procedures such as traffic control, operating room schedule, and dress code. Also, during the time period when the air-handling system was changed, the patient population may also have been sicker and more susceptible to wound infection.
- **Conclusion:** A defective air-handling system in the surgical suite probably resulted in an increased rate of postoperative wound infections among cardiac patients.

The Study: Kyriakides GK, Zinneman HH, Hall WH, Arora VK, Lifton J, DeWolf WC, Miller J. Immunologic monitoring and aspergillosis in renal transplant patients. *American Journal of Surgery* 1976; 131(2): 246–252

- *Research Question:* Did a transplant intensive-care unit exhaust system contaminated with bird droppings result in three cases of *Aspergillus fumigatus* infection in renal allograft patients?
- *Methods:* After three cases of *A. fumigatus* infection occurred within a six-month time span, the entire ventilation system and air-conditioning system servicing the transplant intensive-care unit was examined for possible contamination.
- *Findings:* The air intake system and two of three exhaust ducts proved to be free from contamination but the third exhaust duct was found to be contaminated with *A. fumigatus*, *A. niger*, and *A. flavus*. Further examination of the exhaust duct revealed that the exhaust vent on the hospital roof had lost its protective screen and the exhaust fan was defective, causing air to be suctioned back into the contaminated duct whenever the fan stopped. Bird droppings were present in the duct, and apparently this was the direct cause of the aspergillosis infections. After performing the necessary repairs, there were no further cases of aspergillosis reported.
- *Limitations:* The patients infected with *A. fumigatus* were classified as high risk, and as such, the conclusions in this case study cannot easily be generalized to other populations.
- *Conclusion:* The source of the three cases of aspergillosis among renal allograft patients were due to a malfunctioning exhaust duct contaminated with bird droppings.

The Study: Sherertz RJ, Belani A, Kramer BS, Elfenbein GJ, Weiner RS, Sullivan ML, Thomas RG, Samsa GP. Impact of air filtration on nosocomial *Aspergillus* infections. Unique risk of bone marrow transplant recipients. *American Journal of Medicine* 1987; 83(4): 709–718

- *Research Question:* Can housing bone marrow transplant recipients in HEPA-filtered environments reduce their risk of contracting nosocomial *Aspergillus* infection?
- *Methods:* After it was suspected in 1983 that too many cases of aspergillosis infection were occurring among bone marrow transplant recipients, whole-wall HEPA filters were installed in the bone marrow

transplant unit. The medical records of all bone marrow transplant recipients from 1981 to 1985 were then studied for statistical analysis.

- Findings: The Aspergillus infection rate before installation of HEPA units had been 19% among bone marrow recipients (14 of 74). Among the 39 bone marrow recipients housed in HEPA-filtered units, there were no cases of Aspergillus infection reported.
- Limitations: Observational study creates the possibility of confounding by other patient or environmental differences among the groups.
- Conclusion: HEPA-filtered environments can significantly reduce the risk of bone marrow recipients contracting nosocomial Aspergillus infections.

Sample Design Application:

1. Replace perforated ceiling tiles with nonporous material.
2. Install high-efficiency particulate air (HEPA)-filter air purifiers for all incoming air supply.
3. Install ultra high-efficiency filters (99.97% effective for 0.3 μ particles) in operating rooms.
4. Apply copper-8-quinolinolate-formulation.
5. Seal all windows completely to prevent infiltration.
6. Install timers that can automatically turn on operating room ventilation systems a minimum of two hours before invasive procedures begin.
7. Identify locations of all exhaust vents from isolation rooms or contaminated areas and relocate any that could contaminate the air supply of immunocompromised individuals.
8. Minimize horizontal, dust-collecting surfaces.
9. Use neoprene or other impermeable roofs under heliports.
10. Protect and filter intake ducts near heliports.
11. In operating rooms, use ventilation systems that maintain constant temperature and relative humidity of 50–55% with monitoring systems to ensure they are working.
12. Eliminate standing water due to condensation in cooling system coils using vacuum drainage systems.
13. Install automatic doors between operating rooms and administrative areas to maintain positive pressure of operating room air.
14. Install heat lamps and temperature control anesthesiology machine humidifiers in operating rooms so that staff do not need to increase room temperature in order to rewarm patients.
15. Place bird screens on all exhaust and intake air ducts and fans on all exhaust ducts.

4. Exposure to Daylight and Sunlight

Three studies described below illustrate how natural daylight and outdoor sunlight may affect medical outcomes.

The Study: Barss P, Comfort K. Ward design and neonatal jaundice in the tropics: report of an epidemic. British Medical Journal 1985; 291: 400–401.

- *Research Question:* Does exposure to natural sunlight through glass windows help prevent neonatal jaundice?
- *Methods:* Seven hundred and twenty-four newborn infants in an obstetric ward in the tropics of New Guinea were analyzed in an observational study comparing infants born before, during, and after awnings were built on ward windows that severely limited the intensity of natural light coming through the window glass. An analysis was also conducted of the methods of delivery and postpartum complications during these three different periods.
- *Findings:* In the first four months of the year prior to the modifications, there was only one case of clinical jaundice out of 215 births: an incidence rate of 0.5%. During the first four months of the year in which construction of rain awnings on the outside of windows was performed, the rate increased to 9% (17 cases out of 187 births); and in the first four months of the year following the construction of awnings, the rate reached epidemic proportions at 17% (29 cases out of 175 births). No significant variations were observed in the methods of delivery, neonatal infection rate, birth weights, or postpartum complications over the construction period.
- *Limitations:* Causal inference is limited due to the observational nature of the study. Unexplained fluctuations in the incidence of neonatal jaundice have been reported elsewhere.
- *Conclusion:* Natural sunlight entering glass windows in obstetric units may reduce the rate of neonatal jaundice.

The Study: Lamberg-Allardt C. Vitamin D intake, sunlight exposure and 25-hydroxyvitamin D levels in the elderly during one year. Annals of Nutrition & Metabolism 1984; 28: 144–150.

- *Research Question:* Were low concentrations of serum 25-hydroxyvitamin D (25-OH-D) in three groups of elderly people connected to their exposure to outdoor sunlight?
- *Methods:* Three groups of elderly people were studied: 26 long-stay geriatric patients (Group 1), 24 semi-ambulatory persons residing in an old age home (Group 2), and 22 healthy, ambulatory persons living at home (Group 3). A non-elderly control group comprised 24 healthy employees at a department store with a mean age of 44 years. Blood was drawn four times during the study year and serum 25OH-D concentrations were measured.
- *Findings:* Though there was some seasonal variation in all groups, the serum 25-OH-D concentration was lower in Group 3 (living at home) than in the control group, and the concentration in Group 2 (old age home) was significantly lower than in the controls and in those living at home. The concentration was lowest in Group 1 (long-stay geriatric patients $p < 0.001$) throughout the year.
- Mean vitamin D intake also was significantly lower in Group 2 than the mean intake in the control group and in Group 3 ($p < 0.02$). The mean intake in Group 1 was the lowest and differed significantly from the intake in the control group ($p < 0.001$), Group 3 ($p < 0.001$), and Group 2 ($p < 0.005$). Vitamin D intake/1000 kcal showed similar trends, with Group 1 having the lowest ratio.

- Subjects at home spent 4% less time outdoors during the year than those in the control group, those in the old age home spent about half as much time outdoors as those at home, and those in the long stay facility spent only 17% of the time spent outdoors by the control group.
- Limitations: Elderly patients in Group 1 had lower vitamin D intake levels as well as lower sunlight exposure, which may explain lower 25-OH-D levels. In addition, because this was an observational study, there are likely to be many other differences among the groups that affect vitamin D absorption or conversion besides outdoor sunlight exposure and may thus also be responsible for lower serum 25-OH-D levels.
- Conclusion: Inadequate exposure to natural sunlight due to not going outdoors may be one reason for low serum-OH-D concentration in long-term geriatric patients.

The Study: Beauchemin KM, Hays P. Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders* 1996; 40: 49–51.

- *Research Question:* Do depressed psychiatric patients in sunny rooms stay in the hospital for a shorter term than those in rooms without sun shining in the window?
- *Methods:* In a two-year study, 174 patients admitted to a psychiatric ward with clinical depression were randomly assigned to either sunny or “dull” hospital rooms. The average lengths of stay for the two groups of patients were then compared.
- *Findings:* Patients in the sunny rooms stayed an average of 16.9 days compared to 19.5 days for those in dimly lit rooms. The difference was consistent over all seasons and was statistically significant.
- *Limitations:* Randomness of the room assignments is not fully documented, and patients were not fully compared to determine if other factors could have accounted for the difference in average stay lengths.
- *Conclusion:* Sunny hospital rooms may reduce the amount of time clinically depressed patients spend in the psychiatric unit.

The Design Principle: Maximize natural light or daylight entering healthcare facilities, especially in obstetric, neonatal, and psychiatric units, and maximize access to outdoor sunlight for as many patients as possible.

Sample Design Application:

1. Construct windows without awnings or permanent immovable obstructions to sunlight, especially for psychiatric units and in obstetric areas for neonates.
2. Use ample window area and skylights as much as possible, especially for psychiatric units and in obstetric areas for neonates.
3. Plan psychiatric units for depressed patients with brighter exposures, e.g., southern exposures in the northern hemisphere.
4. Design outdoor areas to be accessible for elderly patients including those with wheelchairs and other disabilities.

Note: This application is general in nature, and must be implemented with respect to local climatic conditions (i.e., low latitude/high altitude sunlight), with appropriate glare-control strategies, and with attention to protecting patients from sunburn. Many commonly prescribed medications and treatments cause patients to be acutely sensitive to direct sunlight. Therefore, access to shade must be provided in outdoor areas.

3. ESTABLISHING A RESEARCH AGENDA

Identifying Patient Groups and Environmental Features for Possible Study

Which patients could have improved outcomes due to changes in the healthcare environment? Which features of the healthcare environment hold the most promise for rigorous investigation? The literature offers little guidance.

Theoretical writings about healthcare facility design have rarely involved clinicians and patients, who could add important perspectives. The physical setting is only one of many facets of care that affect health outcomes for a patient with a particular condition during a specific therapeutic episode. Outcomes-based health-care environmental design theory will mature only after years of scientifically informed dialogue among designers, clinicians, and patients.

First Steps

The first step in outlining a research agenda was to identify the types of patients who would be the best candidates for interventions in the built healthcare environment and the interventions that might affect their medical outcomes. For example, patients in initial studies might be those most apt to benefit from changes in the designed environment or those most vulnerable in current settings.

In order to generate a diverse list of suggested patient groups and environmental features to study, focus groups of clinicians, healthcare researchers, architects, healthcare designers, product managers, healthcare administrators, and facility managers were conducted in November 1997 at the Tenth Symposium on Healthcare Design in San Diego. A focus group of The Center for Health Design's Environmental Quality Work Group was also convened in January 1998 in New York City. This group included architects, designers, and product managers who originally convened to suggest changes to national environmental healthcare design standards.

Focus Group Procedures

Participants were sent advance materials describing the purpose of the focus group. Focus groups were audiotaped. After introductions were made and written consent was obtained from each participant, the moderator gave a brief overview of the background of the research project. Participants were then reminded that the focus group was convened in order to identify patient groups that would benefit most from changes in the healthcare environment, and which features of the environment should be changed. Participants were provided with a written list of the focus group questions:

1. Which group[s] of patients would most benefit from the changes in the healthcare environment?
2. Which features of the healthcare environment should be changed?
3. What outcomes do you expect will improve? Each participant was asked to state at least one suggestion for a patient group to study, and a general discussion ensued. After the discussion was over, participants were asked to write down two choices of patient groups, with features to change and outcomes that they thought would be affected.

Data collected from each focus group was transcribed and analyzed. Appendix C lists each patient group suggested, how many focus group participants submitted this as one of their two choices, setting and environmental features to be changed, and the outcomes that the participants thought would be improved.*

Criteria for Selection of Patient Groups

In order to determine criteria by which patient groups, settings, and environmental features should be selected for study from among those recommended, a focus group of The Center for Health Design Research Committee was convened in January 1998 in San Francisco.

This group consisted of researchers specializing in the effects of healthcare design and architecture on patient medical outcomes. Criteria recommended by the Research Committee for deciding which study to select on the effects of the built healthcare environment on outcomes are listed in Table 5 (see PDF version).

Each suggested patient group was rated by the authors as 1, low; 2, medium; or 3, high; using these criteria (see Appendix C in PDF version). Using the ratings and the investigators' judgment, two general patient groups were selected for further consideration: seriously or chronically ill children in acute or chronic care facilities, and physically frail but cognitively intact elderly residents of long-term care facilities. These groups received high ratings, and the investigators judged based on prior clinical and research experience that possible projects in these groups were important, politically appealing, credible, and feasible.

Possible Environmental Features for Study

Focus group participants described environmental interventions that might affect medical outcomes for each of the patient groups selected. The interventions described are grouped below according to the type of outcome they were thought to affect.

Elderly physically frail, but cognitively intact residents of long-term facilities

Quality of Life: Well-being

Aspects of well-being that could be improved for this population by changing environmental features include comfort, depression, sense of dignity, hope, enjoyment, self-esteem, fulfillment with life, and overall patient satisfaction with the environment. Environmental changes that might affect well-being that were mentioned by respondents included:

- Color
- Temperature
- Landscapes
- Pleasant outdoor views
- Gardens, courtyards, and patios with rails and walkways permitting walkers and wheelchairs, to allow physically impaired patients to enjoy them
- A flexible environment to accommodate increasing level of care if needed so the patient does not need to move from the same home, e.g., using a mobile home
- Design reasonable walking distances to common spaces from units
- Smaller domestic scale, residential amenities
- Areas for intergenerational interactivity (kids, parents, animals) and playgrounds
- Equipment to create connections with people through the Internet
- Positive distraction

Functioning

Important functional outcomes mentioned for this group included independence in activities of daily living or autonomy, quantity, and quality of social interaction (especially during dining), continence, e.g., a mobile home.

Environmental changes thought to affect functioning that were suggested by the respondents included:

- Bathroom design including more space to transfer to toilet, space to hang clothing, space to admit a walker
- Walking distances that are reasonable to common spaces from units, or home settings mobile units with smaller domestic scale, residential amenities

- Areas for intergenerational interactivity (kids, plants, animals) and playgrounds
- Flexible layout as above to accommodate for different levels of care
-

Clinical Outcomes

Clinical outcomes that participants thought could be improved through environmental changes for this population included medication intake, falls, mobility, safety, agitation, bedsores, and length of stay.

Environmental changes thought to potentially improve those outcomes included reducing noise levels, changing lighting to have adequate intensity but without glare, and avoiding confusing color patterns that affect depth perception, installing wall-to-wall carpeting, and eliminating obstacles and scatter rugs.

Seriously ill children in acute-or chronic-care facilities.

Focus group participants described that certain environmental interventions might affect clinical outcomes for seriously ill children in acute- or chronic-care pediatric hospitals. The participants suggested the importance of several overriding elements in design of health-care facilities for children that affect all types of outcomes:

- The facility from outside to the lobby and throughout the interior should convey that it is a special place for infants, children, and adolescents.
- The facility should promote family's important role in helping infants, children, and adolescents cope with healthcare experiences, and feel in control and comfortable. Thus, there should be accommodations for parents that are efficient for assisting and caring for their children. Specific interventions are described below under the outcome they were thought to affect.

Quality of Life: Well-being

Aspects of well-being that could be improved for this patient population by changing environmental features include children's comfort, empowerment and self-esteem, and family stress. Suggested environmental changes that were thought to affect these aspects of wellbeing included:

- Color
- Temperature
- Light
- Sound
- "Homelike," residential-type design features
- Appropriate environment for siblings and parents
- A general "fun" environment
- "Personalization" with personal belongings

- Privacy for parents for discussions about prognosis, so that children will not overhear

One aspect of well-being mentioned that could be improved specifically for infants by changing environmental features was neonatal relaxation and bonding with their parents. Suggested environmental changes for neonates included:

- Individual rooms for each baby with parents
- Music in cribs or in room

Functioning

Aspects of functioning that could be improved for seriously ill children by changing environmental features in hospitals include physical functioning and social interaction with peers. Environmental changes that might affect functioning that were mentioned by respondents included:

- Access to outdoor play
- “Star Bright” Internet network for virtual connection with others
- Parent accommodations such as lounge, showers, and kitchen
- Family sleeping area
- Conference room so child does not hear parent/provider discussions
- Transition room for going home to teach self-care

Environmental changes that might affect function for neonates that were mentioned by respondents included:

- Accommodations for parents that facilitate contact/touch between parent and child
- Family sleeping area

Clinical Outcomes

Changes in clinical outcomes that participants thought might occur through environmental changes for the children and adolescents included:

- Decreased medication intake
- Decreased stress
- Decreased length of stay
- Increased recovery rate

- Decreased recovery time
- Reduced pain
- Increased psychological and physical peacefulness and increased psychological adjustment

Neonatal clinical outcomes that participants thought could occur through environmental changes included:

- Weight gain
- Reduced abuse by parents due to increased bonding of parent and child
- Reduced length of stay

Having reviewed some of the possible features of the environment that could be changed to improve patient medical outcomes for these groups, the next chapter outlines criteria that help us to decide upon features for intervention, and an agenda for planning a trial to attempt to demonstrate the possible impact of the built healthcare environment on patient medical outcomes.

4. THE FUTURE RESEARCH AGENDA

Toward a Research Agenda: Methodological Concerns

No matter which environmental features or which types of patients are studied in the future, some important methodologic recommendations would make research in this field more cost-effective and add to its impact.

Studies of the effect of the healthcare environment on patient outcomes need to be as rigorous as those of any other healthcare intervention. The best studies, as has been emphasized, are randomized controlled trials and those that assign the same subjects to different conditions in random sequence with paired data analysis. These strategies help ensure that no significant confounding factors affect the outcomes when the patients are observed under the environmental conditions being compared.

True blinding is difficult to achieve when environmental features are the subjects of the research. At the very least, however, new features should be allocated among patients at random.

When randomization is not possible, observational studies should be planned that take into account the entire conceptual model of interactions affecting patient health outcomes. All variables that may influence clinical outcomes for the patients being observed, including patients' personal characteristics, medical interventions,

and aspects of the healthcare setting, need to be measured to make sure there are no systematic differences among the different patient groups or study sites.

Proposed Master Plan: Recommended Next Steps

Appendix D provides a master plan and timetable for the next steps in an agenda to investigate, with scientific rigor, whether the built environment plays a role in healthcare outcomes, and if so, what the types and strengths of such effects are.

Should they validate the hypothesis that the environment matters, the steps described below will move the field toward the ultimate development of appropriate design standards and guidelines.

Year One: In the next six months, groups of patients and clinicians from each of the two groups will be convened to discuss and make recommendations as to the types of healthcare environmental changes that would produce the greatest health outcome benefits for each of the two specific groups of patients selected for initial study. The decision between the two groups as well as which specific environmental features and outcomes will be targeted will continue to be based on the criteria in Table 5. It is expected that these criteria will be reapplied after environmental features and outcomes have been defined through the focus groups with clinicians, caregivers, and patients.

Years One to Four: In the following two years, one or more pilot studies will be undertaken on the basis of these recommendations. The pilot study or studies will be designed to test environmental intervention procedures, outcome evaluation measures, and analytic techniques, in preparation for an expanded, longer-term investigation. During the period of the pilot studies, and with their results in hand during the following six months, a definite proposal for a rigorous five-year intervention study will be prepared, submitted for external funding, and refined as needed.

Years Five to Nine: Finally, a rigorous, large-scale, experimental study will be undertaken to demonstrate definitively whether or not a change in the healthcare environment will improve important health outcomes. This study would last an estimated five years, including a year for writing a report for publication and dissemination of results.

Conclusion

There is suggestive evidence that aspects of the designed environment exert significant effects on clinical outcomes for patients receiving medical care. However, the case must still be proved. Accurate, valid scientific data based on careful, credible studies are needed.

More than \$16 billion is being spent in health facilities construction in the United States this year. Yet with outlays at this level, there is near total ignorance of the impact of the design of the built environment on the effectiveness of clinical intervention. In this context, investment in the research program outlined above is a modest yet vital first step with the potential to yield cost savings and improved health through the design of the healthcare environment.

APPENDICES

APPENDIX A: Literature Search Methods

The Ovid and Pubmed search engines were used to search the Medline database. The Health Star database was searched using Ovid only. All searches were limited to English-language articles.

Other potentially pertinent studies cited as references in the articles located were retrieved and read as well. Finally, The Center for Health Design staff and members of its Healthcare Design Research Committee suggested additional literature sources, which were also reviewed.

Health Facilities*

The search began with the keyword “health facilities”^{*} from the Medline and Health Star subject heading tree. Additional keywords representing specific types of health facilities were identified through the subject heading tree. The following available specific terms were considered relevant to effects of the healthcare environment on patient outcomes and were included in the search:

- Academic medical centers
- Ambulatory-care facilities
- Birthing centers
- Dental facilities
- Health facilities, proprietary
- Hospital units
- Hospitals
- Leper colonies
- Medical office buildings
- Nurseries
- Physicians’ offices

- Rehabilitation centers
- Residential facilities
- Health facility environment
- Health facility size
- Health design and construction

The following specific words related to health facilities were not considered relevant to the topic under study and were not used in the search:

- Bed occupancy
- Biological specimen banks
- Health facility laboratories
- Pharmacies

In addition to health facilities and the related specific terms above, the keyword combinations below were also searched. For phrases marked with an asterisk (*), additional articles were located using Ovid's "explode" function. This identified a larger number of articles, many of which were not relevant, but sometimes a few more relevant articles were located.

- Outcomes and process assessment/health facilities
- Room size
- Patients' rooms and size
- Room scale
- Room privacy
- Hospital and room size
- Cross infection and health facilities
- Cross infection and ventilation
- Health facilities and ventilation
- Room organization
- Environmental control by patient
- Room flow or interactivity
- Air and ventilation
- Health facilities and humidity*
- Health facilities and lighting*
- Health facilities and sunlight*
- Health facilities and aroma*
- Health facilities and noise*

- Health facilities and music*
- Health facilities and temperature*
- Furnishings
- Health facilities and climate/landscape*
- Health facilities and equipment design*
- Windows
- View out window
- Disinfection
- Sterilization

The keywords listed above served as initial search words. The number of titles identified depended on the specificity of each keyword.

Medline (PubMed)

In using the PubMed program, the same keywords were employed. However, PubMed has a function that allows a list of articles to be requested that are related to a specific article. By this function, “See related articles,” a significant number of additional titles were obtained that increased the volume of the search significantly.

Criteria for Selection and Elimination of Articles

Once the list of titles was compiled from the two databases, a number of criteria were used to eliminate or include an article for further investigation. If the title of the article did not clearly indicate whether it was relevant, the abstract was retrieved. If the abstract also did not clarify if the article was relevant, the article was retrieved. Articles were excluded for the following reasons:

1. The article is not relevant to the topic. For example, when searching using the keywords “color and patient recovery,” articles were found that discuss the recovery of color vision in patients after eye surgery. Irrelevant articles were classified as those that either a) do not discuss the health facility environment, or b) do not discuss how the health facility environment affects patients’ outcomes
2. The article is on the correct topic, but gives no experimental data evaluating effects of the environment on patient outcome, e.g., an editorial.
3. The article does not discuss human subjects.

APPENDIX B: Summary Table of Extant Studies of Effects of the Healthcare Environment on Patient Outcomes

See PDF version for Appendix B, the Summary Table of Extant Studies of Effects of the Healthcare Environment on Patient Outcomes.

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