STATUS REPORT (1998): AN INVESTIGATION TO DETERMINE WHETHER THE BUILT ENVIRONMENT AFFECTS PATIENTS' MEDICAL OUTCOMES

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THE CENTER FOR HEALTH DESIGN, INC.

Vision

To create a future where environments support the highest level of human health, well-being, and achievement in all aspects of life and work.

Values

As the leaders of a global community, we encourage and support:

- Organizations that demonstrate a commitment to valuing the dignity of all human beings.
- Those who want to learn how to use the built environment to improve human health and well-being.
- Intentional actions that are consistent with the vision, mission, purpose, and goals of The Center for Health Design.
- And, as leaders, we will continuously strive toward modeling these values. In fact, we are willing to be held accountable to our commitment to do so.

Mission

To advance the state of life-enhancing environmental design by demonstrating the value of design in improving health and the quality of life.

Purpose

To advance the state of life-enhancing environmental design by:

- Serving as the internationally recognized source of high-quality educational programs.
- Supporting the development of rigorous research that will significantly advance the art and science of health design.
- Developing and promoting the practical application of life-enhancing design.
- Developing a worldwide network of supportive individuals, businesses, and allied organizations.
- Supporting the needs and interests of network constituents.
- Serving as a clearinghouse for resources, including books, periodicals, articles, audio- and videotapes, project data, facility tours, and product information.

Goals

To realize The Center's vision by directing resources at:

- Education — Increasing the awareness of the value of design for the:
  - healthcare industry
  - design profession
  - general public
- Research — Causing 50% of the healthcare institutions in America to have incorporated The Center's recommended five key design elements into their institutions and cultures by the end of 2000.

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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, 1860[2]

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 partic-

ular 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 healthcare 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]

— David O. Weber
Berkeley, California, September 1996

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[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 well-being, 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 healthcare 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. 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.

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 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. Seventy-four of the studies (88 percent) demonstrated

TABLE 1

Selected Features for the Healthcare Environment Included for Literature Review

- Room scale
- Room size
- Room privacy
- Room organization
- Environmental control by patient
- Room flow or interactivity (how much it permits interactions with staff and others)
- Lighting
- Color of walls, furnishings
- Texture or finish of walls, furnishings
- Pattern of walls, furnishings, artwork
- Air and ventilation
- Aroma
- Noise
- Music
- Temperature
- Type of furnishings
- Relationship with nature
- Equipment design
- Windows
- Type of window view

TABLE 2

Patient Outcomes Included in Literature Search

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

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 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.

TABLE 3
Literature Search Yield

Database	Total ID'd	Possibly Relevant	Met Inclusion Criteria
Health planning (1966–9/1995)	8,087	177	17
Health Star (1975–9/1998)	21,748	170	5
Medline Ovid (1966–9/1998)	48,800	831	52
References from articles	126	41	10
Total	**78,761**	**1,219**	**84**

Conclusions

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.

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.

TABLE 4

Research Study Designs: Encountered in the Literature Survey

STUDY DESIGN	DESCRIPTION, STRENGTHS AND WEAKNESSES, SIMILAR ALTERNATIVES
Randomized controlled trial *Type code:* 1	*Description:* Patients are assigned in random order to conditions with and without a certain environmental feature. *Strength:* Excellent for drawing conclusions about whether that feature really matters. *Weakness:* It is often difficult to assign environmental conditions randomly.
Type code: 1b	*Similar alternative:* Consecutive or apparently unbiased systematic assignment of subjects to conditions with or without a certain environmental feature. *Random assignment is always preferable to avoid unintended bias.*
Experimental trial with paired data *Type code:* 2	*Description:* The same patients are *assigned* to different environmental conditions at different times, *under the direction of investigators*. Each patient serves as his or her own control for comparisons. *Strength:* Excellent for concluding if an environmental feature matters. Conclusions are stronger if patients are randomly assigned to receive one or the other condition first *Weakness:* It is not always possible to treat the same patient under different conditions.
Type code: 2b	*Similar alternative:* Experimental trial using the same group of patients with unpaired data analysis. The same patients are assigned to different conditions at different times, but only the average results for the entire group are compared under different conditions, rather than examining each subject as his own control. *Paired data analysis is always both possible and preferable.*

TABLE 4, *cont.*

Research Study Designs: Encountered in the Literature Survey

STUDY DESIGN	DESCRIPTION, STRENGTHS AND WEAKNESSES, SIMILAR ALTERNATIVES
Observational study with paired data *Type code:* 3	*Description:* The same patients are observed under different environmental conditions *in the course of routine care. The environmental conditions are not controlled by the observers but are those that occur naturally.* Each patient serves as his own control. *Strength:* A sound study design for drawing conclusions, although somewhat weaker than an experimental trial with paired data. *Weakness:* Because the study does not assign and control the environmental conditions, other aspects of the setting could differ besides the environmental feature of interest.
Type code: 3b	*Similar alternative:* Observational study using the same patients but with unpaired data analysis. The same patients are assigned to different conditions at different times, but only the average results for the entire group are compared under different conditions, rather than examining each subject as his own control. *Paired data analysis is always both possible and preferable.*
Observational study of different groups *Type code:* 4	*Description:* Groups of patients are compared in different environments in the course of routine care. If performed in sequential time periods, perhaps before and after a design change or policy change, such studies are referred to as "natural history" studies. *Strength*: Easiest to organize. Study can be made relatively stronger by identifying and measuring all differences among groups that influence patient outcomes and analyzing possible effects on results. *Weakness:* Because there may be too many other differences among the groups of patients to account for them comprehensively and accurately, this is the weakest study design.
Type code: 4b	*Similar alternative:* Experimental trial assigning different patients nonrandomly and in a possibly biased fashion to different environmental conditions.

2. A MODEL
Environment and 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 illustrates this concept schematically.

Figure 1. Factors affecting patient health outcomes

- *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 healthcare 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 healthcare 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 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.

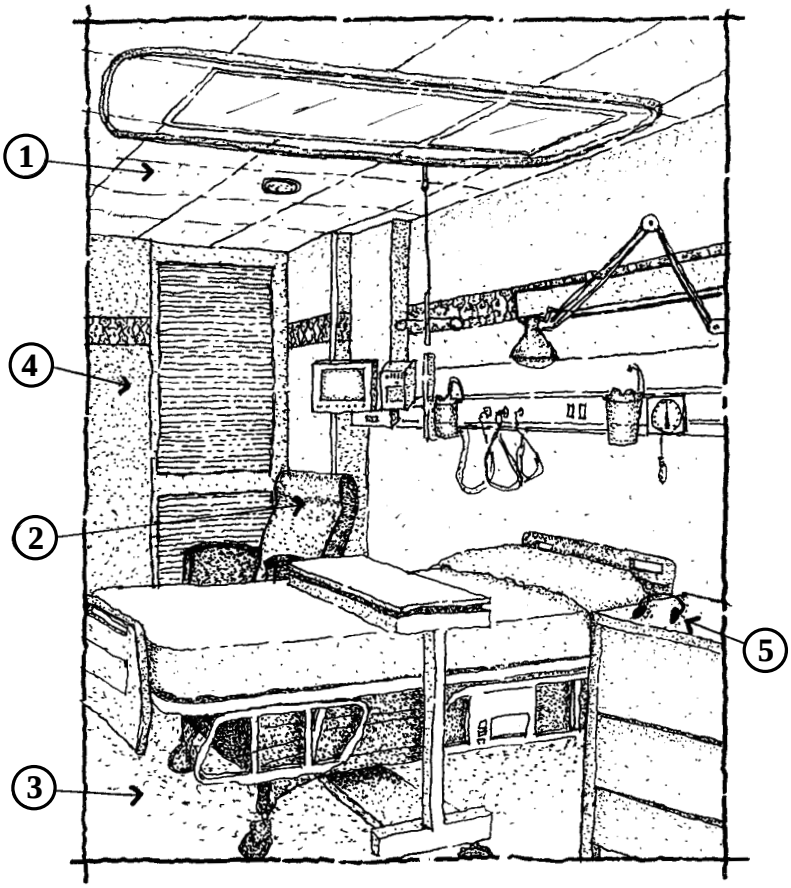

Figure 2. Critical Care Room Incorporating Environmental Strategies to Promote Quiet (courtesy of Watkins, Carter, Hamilton Architects)

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 lat-

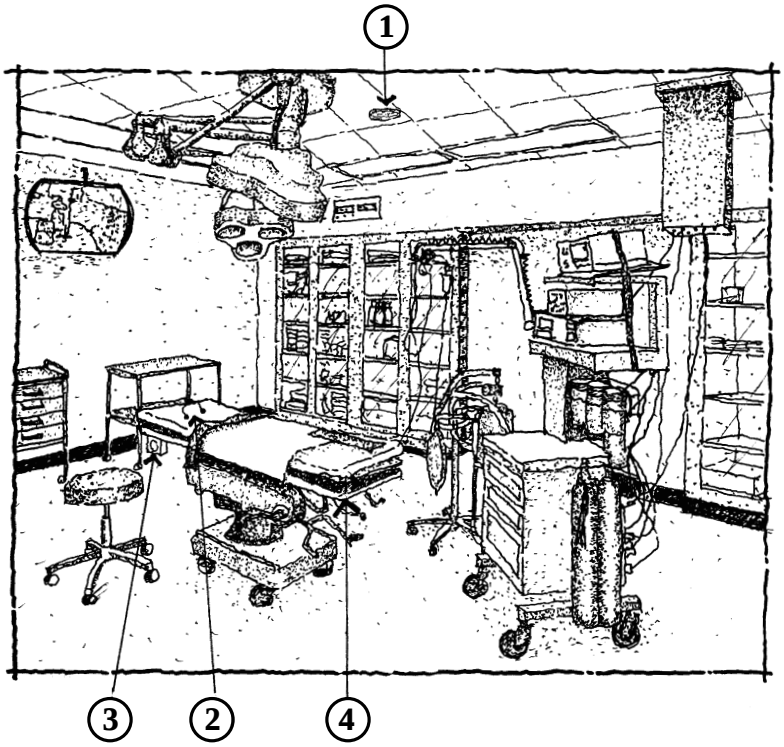

Figure 3: An Operating Room Incorporating Environmental Strategies for Providing Music during Surgery (courtesy of Watkins, Carter, Hamilton Architects)

eral 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 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-8-quinolinolate 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 0.3µ 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 25-OH-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 healthcare 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.

Each suggested patient group was rated by the authors as 1, low; 2, medium; or 3, high; using these criteria (see Appendix C). 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,

TABLE 5

Criteria Recommended by Research Committee for Selecting Patient Groups and Environmental Interventions to Study

IMPORTANCE

- Vulnerable patient population:
  - Reactive/fragile population; unable to act on their own behalf
  - Long stay in health facility
- Important outcome affected; something that makes a big difference to people; something that affects health in a significant way
- Generalizable to other populations, not just to a narrow or esoteric group

POLITICAL APPEAL

- Public resonance and identification (combination of population, outcome, setting, and features changed that seem important to a wide variety of common people, the man on the street)
- Administrator resonance: e.g., reduces length of stay, costs

CREDIBILITY

- Practitioner resonance—including caregivers and designers. May need to be multidimensional intervention for designers to believe it works
- Direct cause/effect relationship of the built environment to the outcome; e.g., the environment represents medical treatment in the situation studied
- Rigorous enough study for the scientific community to accept the cause/effect relationship of the environment

FEASIBILITY

- Doable/feasible research:
  - Homogenous study population
  - Feasible experiment design
  - Data easily obtained (already collected will be best)
  - Intervention easily accomplished during the research phase
- Feasible intervention: Actionable implication that would not face a lot of industry barriers when others attempt to apply it

* Respondents listed some outcomes that go beyond the medical outcomes listed in Table 2. These are listed for completeness, but medical outcomes were given more importance when rating studies used the criteria described in Table 5.

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 healthcare facilities for children that affect all types of outcomes:

1. The facility from outside to the lobby and throughout the interior should convey that it is a special place for infants, children, and adolescents.
2. 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 well-being 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 tech-

niques, 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.

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

Bibliographic Information	Environmental Variable(s)	Study Population
Abzug MJ, Gardner S, Glode MP, et al. Heliport-associated nosocomial mucormycoses [letter]. *Infection Control & Hospital Epidemiology* 1992; 13(6): 325–326	Gravel under helipad in proximity to ventilation system intake vents vs. impermeable neoprene roof, high-efficiency particulate air (HEPA) filters in oncology patient rooms	Newly diagnosed leukemia patients in a pediatric teaching hospital (n=168)
Ackerman B, Sherwonit E, Williams J. Reduced incidental light exposure: effect on the development of retinopathy of prematurity in low birth weight infants. *Pediatr* 1989; 83: 958–962	Reduced light exposure from 55 to 15 footcandles (using a blanket to cover the top part of the isolette)	Premature infants in the intensive care nursery at Yale–New Haven Hospital (n=290)
Anderson JD, Bonner M, Scheifele DW, et al. Lack of nosocomial varicella in a pediatric hospital with negative pressure ventilation patient rooms. *Infect Control* 1985; 6(3): 120–121	Negative pressure ventilation	Pediatric patients in a Vancouver hospital (n=164)

† Codes for Study Designs

1 = Randomized control trial
1b = Experimental, consecutive or apparently unbiased systematic assignment
2 = Experimental, paired
2b = Experimental, unpaired, same group at two time points
3 = Observational paired
3b = Observational, unpaired, same group at two time points
4 = Observational, unpaired
4b = Observational, unpaired, nonrandom assignment

Study Design†	Outcomes	Findings	Comments on Study Validity
4	Cases of mucormycosis	No cases of mucormycosis observed 1978–1985, 3 cases in 1985, and no cases 1986–1991. Heliport was constructed in 1983, with 55 transports in 1984 and 77 in 1985. Infections occurred after heavy heliport use. It was found that gravel contaminated with zygomycetes was blown into the ventilation system intake ducts by the helicopter	Observational design permits confounding, but results and demonstration of pathway of pathogenesis are highly suggestive of a causal link
4	Incidence of retinopathy of prematurity	There was no difference in the incidence and severity of retinopathy of prematurity between groups exposed to different intensities of light	Historical control group allows confounding; however, groups did not differ in known predictors of retinopathy including oxygen therapy, gestational age, and birth weight
4	Incidence of nosocomial chicken pox	Children in the unit with negative pressure rooms had lower incidence of nosocomial chicken pox than those on a regular ward	1) Follow-up of only English-speaking patients in Vancouver 2) Other differences between the two units unknown 3) No characterization of illness states of patients on the two wards; possible confounding

Additional Codes

[1] Consecutive assignment

[2] Uncontrolled study; asks patients if they believe noise affected their sleep

[3] Systematic assignment

Bibliographic Information	Environmental Variable(s)	Study Population
Anderson RL, Mackel DC, Stoler BS, et al. Carpeting in hospitals: an epidemiological evaluation. *J of Clinical Microbiology* 1982; Mar: 408–415	Carpeting or bare floor in patient rooms	Patients randomly admitted to rooms with (CR) and without (NCR) carpeting in a pediatric hospital (n=69)
Baker CF. Discomfort to environmental noise: heart rate response to SICU patients. *Crit Care Nurs Q* 1992; 15(2): 75–90	Noise level and type of noise	SICU patients in a private Southwest nonteaching hospital after abdominal, carotid endarterectomy, or peripheral vascular surgery (n=28)
Baker CF, Garvin BJ, Kennedy CW, et al. The effect of environmental sound and communication on CCU patients' heart rate and blood pressure. *Res Nurs Health* 1993; 16: 415–421	Noise level and type of noise	Adults admitted to a CCU in a large midwestern teaching hospital (n=20)
Baldwin S. Effects of furniture rearrangement on the atmosphere of wards in a maximum-security hospital. *Hosp Commun Psychiatry* 1985; May 36(5): 525–528	Rearrangement of furniture from nonsocial patterns into group seating	Patients with severe mental retardation, psychogeriatric patients, and those with various psychiatric disorders in a maximum-security hospital in England (n=260)
Barss P, Comfort K. Ward design and neonatal jaundice in the tropics: report of an epidemic. *Br Med J* 1985; 291: 400–401	Awnings reducing natural light	Newborn infants in the obstetric ward of Provincial Hospital in the tropics of Papua, New Guinea (n=724)
Baumgart S, Engle W, Fox W, et al. Effect of heat shielding on convective and evaporative heat losses and on radiant heat transfer in the premature infant. *J Pediatr* 1981; 99: 948–956	Heat shielding using plastic walls around beds and plastic blankets	Premature newborns, most with respiratory distress, without renal, cardiovascular, or CNS disorders at The Children's Hospital of Philadelphia (n=10)

Study Design†	Outcomes	Findings	Comments on Study Validity
1	Hospital-acquired infection rate. Proportion of patients colonized with typable and nontypable organisms found on the floor or carpet	Typable organisms (including *E. coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Staphylococcus aureus*) were isolated more frequently from patients in carpeted rooms than those in rooms with bare floors. However, patients in both types of room had similar rates of colonization with all organisms (whether typable or nontypable) found on the floor, and similar rates of hospital-acquired infection. Hospital-acquired infections were not associated with organisms found as contaminants of the carpet or floor	Strong study design with random assignment. However, sample size provides inadequate power to detect possibly significant differences in hospital-acquired infections
4	Heart rate	Mean heart rate was higher during talking in the room and nontalking noise compared with talking inside the room and ambient noise only	1) Very small sample size 2) Nonrandomized study; noise type and level may be confounded by different types of patients experiencing each type of noise —not examined or reported on
3	Blood pressure and heart rate	Subjects had higher maximum heart rates during room conversation than during background sound. This effect was independent of the decibel level.	1) Very small sample size may limit generalizability 2) Prior state of the patient before observation may confound the noise level and type of noise; repeated measures analysis using each patient as his own control is otherwise a fairly strong design
3	Seclusion rate, casualty incidents, "points" earned by residents for good behavior, resident perception of the ward, nursing observations of residents' behavior	During the study the intervention wards had lower rates of patients requiring seclusion, a lower rate of casualty incidents, and nurses' reports showed favorable attitudes and improved social interaction	1) Fairly strong design due to stable group of patients over time 2) No reliability or validity testing of outcome measures is reported
4	Bilirubin concentration, neonatal bilirubin requests (jaundice cases)	Decreasing the amount of sunlight entering the ward significantly increased the rate of neonatal jaundice from 0.5% (1 of 215) to 17% (29 of 175)	Observational study permits confounding; validity is increased because the study identified and measured other elements that influenced patient outcomes
2	Insensible water losses and radiant power demand	Water losses were lower in the shielded conditions. Radiant power demand was the same for control and walled environments but lower when infants were covered with plastic blankets. Thin plastic blankets were the most effective heat shields.	1) Excellent study design, experimental controlled trial with paired data 2) Reliability and validity of measures not described but good face validity

Bibliographic Information	Environmental Variable(s)	Study Population
Beauchemin KM, Hays P. Sunny hospital rooms expedite recovery from severe and refractory depressions. *J Affective Disorders* 1996; 40: 49–51	Sunny vs. nonsunny or "dull" rooms	Psychiatric inpatients with depression in a hospital in Edmonton, Alberta, Canada (n=174)
Belgaumaker TK, Scott KE. Effects of low humidity on small premature infants in servocontrol incubators. *Biol Neonate* 1975; 26: 348–352	Humidity level	Premature newborns in servocontrol incubators at Grace Maternity Hospital, Halifax, NS (n=19)
Bell EF, Gray JC, Weinstein MR, et al. The effects of thermal environment on heat balance and insensible water loss in low birth weight infants. *J Pediatr* 1980; 96: 452–459	Temperature level	Premature newborns in incubators at Women's and Infants Hospital of Rhode Island (n=12)
Blackburn S, Patteson D. Effects of cycled light on activity state and cardiorespiratory function in preterm infants. *J Perinatal Nurs* 1991; 4(4): 47–54	Lighting level, light cycling vs. continuous lighting	Preterm infants born at or prior to 34 weeks gestation, admitted to a tertiary neonatal intensive care unit, and with no history of major anomalies or maternal drug addiction (n=18)
Blankfield RP, Zyzanski SJ, Flocke SA, et al. Taped therapeutic suggestions and taped music as adjuncts in the care of coronary-artery-bypass patients. *Am J Clin Hypnosis* 1995; 37(3): 32–42	Taped therapeutic suggestion and music intraoperatively and postoperatively	Coronary-artery-bypass-surgery patients at two community hospitals in Cleveland, Ohio (n=95)
Bourke L. Severe burn caused by an operating room light. *Anesthesiology* 1993; 79(1): 171–173	Unfiltered operating room light	62-year-old man undergoing radical retropubic prostatectomy surgery (n=1)

Study Design†	Outcomes	Findings	Comments on Study Validity
1	Length of hospital stay	Patients in sunny rooms stayed an average of 16.9 days, whereas those in "dull" rooms stayed an average of 19.5 days. The difference was consistent over all seasons during a period of two years (Oct. '93–Sept. '95)	Randomized study with comparison of patient groups
2	Apneic spells, mild and severe	Severe apneic spells were more frequent in low than high humidity	1) Strong study design, experimental controlled trial with paired data 2) Small sample size may limit generalizability
2	Insensible water loss, evaporative heat loss, nonevaporative heat loss, oxygen consumption	Higher temperature produced a rise in water loss and evaporative heat loss and a fall in nonevaporative heat loss. Lower temperature produced an increase in oxygen consumption and heat loss	1) The authors discuss some threats to the validity of measures that may cause them to estimate incorrectly 2) Strong study design, experimental trial with paired data
4b	Heart rate, motor activity, and respiratory rate	Infants in cycled lighting had lower heart rates and motor activity in the low light level than the high light level; there were no day-night differences in the continuous lighting group	1) Very small sample size 2) Nonrandomized study design permits confounding by unmeasured variables 3) No information about how these neonates compare to the general neonatal population in nontertiary nurseries
1	Length of stay, narcotic use, anxiety, recovery progress, depression, activities of daily living, cardiac symptoms	No differences between the groups were statistically significant, although groups listening to tapes reported less pain and took fewer narcotics	Randomized design supports validity
4	Severe burn	Patient exposed to unfiltered tungsten halogen light developed a partial, possibly full-thickness burn	Despite this being a case study with no control information recorded, there is strong causal inference that the light exposure caused the burn, due to the temporal relationship, the unusual nature of the outcome, and full understanding of the causal pathway

Bibliographic Information	Environmental Variable(s)	Study Population
Caine J. The effects of music on the selected stress behaviors, weight, caloric and formula intake, and length of hospital stay of premature and low birth weight neonates in a newborn intensive care unit. *J Music Therapy* 1991, XVIII(4): 180–182	Music in a newborn intensive care unit (NBICU)	Male and female preterm and low birth weight newborns in the newborn intensive care unit at The Tallahassee Memorial Regional Medical Center (n=52)
Cotterill S, Evans R, Fraise AP. An unusual source for an outbreak of methicillin-resistant *Staphylococcus aureus* on an intensive therapy unit. *J Hospital Infection* 1996; 32: 207–216	Relative location of ICU isolation room exhaust ducting and windows above other ICU beds	Patients in an intensive-therapy unit (ITU) in the United Kingdom (n=100)
Davis-Rollans C, Cunningham SG. Physiologic responses of coronary care patients to selected music. *Heart and Lung* 1987; 16(4): 370–378	37-minute tape recording of three selected music pieces played in one of three different permutations	CCU patients at Kitchener-Waterloo Hospital in Ontario, Canada (n=24)
deSilva MI, Rissing JP. Postoperative wound infections following cardiac surgery: significance of contaminated cases performed in the preceding 48 hours. *Infect Control* 1984; 5(8): 371–377	Changes to air-handling system to increase outside air changes, improve filter efficiency, maintain constant temperature and humidity, increase positive pressure of operating room air	Cardiac-surgery patients at the VA Medical Center in Augusta, Georgia (n=506)
Dolce JJ, Doleys DM. Narcotic utilization for back pain patients housed in private and semi-private rooms. *Addictive Behaviors* 1985; 10: 91–95	Private vs. semiprivate rooms	Orthopedic inpatients with pain-related back disorders at University of Alabama, Birmingham (n=89)
Dubois JM, Bartter T, Pratter MR. Music improves patient comfort level during outpatient bronchoscopy. *Chest* 1995; 108(1): 129–130	Music during bronchoscopy vs. no music	Bronchoscopy outpatients at Cooper Hospital/University Medical Center of the UMDNJ/Robert Wood Johnson School of Medicine at Camden, New Jersey (n=49)
Everett WD, Kipp H. Epidemiologic observations of operating room infections resulting from variations in ventilation and temperature. *Am J Infect Control* 1991; 19(6): 277–282	Ventilation system functioning and air changes or operating room temperature	Surgery patients at a publicly funded military facility (n=903)

Study Design†	Outcomes	Findings	Comments on Study Validity
1	Initial weight loss, daily average weight, formula and calories length of NBICU and total hospital stays, daily group mean of stress behaviors	Infants randomized to music had significantly lower stress levels, improved feeding, lower initial weight loss, and shorter length of hospital stay compared to infants without auditory stimulation	Strong study design
4	Infection with methicillin-resistant *Staphylococcus aureus* (MRSA)	The cases of MRSA were initially nursed in the same bed or in an adjacent bed. The bed was located under an open window near exhaust ducting from an isolation room	Findings highly suggestive although not completely conclusive due to inability to sample the ventilation system air in the side room
2	Change in emotional state, heart rate, respiratory rhythm, heart rhythm	There were no statistically significant changes in specified physiologic variables during the music period. Patients had a happier emotional state after music was played	Small sample size limits generalizability. Observational study design permits confounding but pairing strengthens the causal inference
4	Postoperative wound infection	Wound infections increased after relocation from 4 of 320 (1%) to 7 of 77 (9%); after changes to air handling, the infection rate decreased (7 of 77, 9%, before vs. 1 of 109, < 1% after)	Observational study permits confounding by alterations in operating procedure that were made concurrently
4	Use of narcotics as a measure of pain	Patients in private rooms requested more narcotic injections. However, this difference was not statistically significant after adjusting for other variables	Small sample size given the number of other variables being adjusted for
1	Overall comfort, cough, dyspnea	The use of music was associated with significantly greater comfort and less coughing. There was no significant difference in rating of dyspnea during the procedure	Strong study design
4	Clean wound infections	When the ventilation system was inadequate during the summer months, the infection rate was 3.523 times higher than in winter. When the ventilation system was fixed, the rates did not increase in summer	Historical control allows confounding by other unknown environmental factors or changes in operative procedures

Bibliographic Information	Environmental Variable(s)	Study Population
Fridkin SK, Kremer FB, et al. *Acremonium kiliense endophthalmitis* that occurred after cataract extraction in an ambulatory surgical center and was traced to an environmental reservoir. *Clin Inf Dis* 1996; 22: 222–227	Contaminated operating room ventilation system	Patients in ambulatory surgical center (n=216)
Gast P, Baker C. The CCU patient: anxiety and annoyance to noise. *Crit Care Nurs Q* 1989; 12(3): 39–54	Noisy vs. non-noisy hour	Patients admitted to the CCU of a large midwestern university hospital (n=20)
Geden EA, Lower M, Beattie, at al. Effects of music and imagery on physiologic and self-report of analogued labor pain. *Nurs Res* 1989; 38: 37–41	Music: easy listening, rock, self-selected music, vs. a dissertation	Volunteer nulliparous subjects exposed to a pain stimulator at levels reported to simulate labor pain (n=50)
Giradin BW. Lightwave frequency and sleep-wake frequency in well, full-term neonates. *Holistic Nurs Prac* 1992; 6(4): 57–66	Wavelength of light (light intensity) in a neonatal well-baby nursery	Hispanic neonates in an urban county hospital in Southern California (n=100)
Giunta F, Rath J. Effect of environmental illumination in prevention of hyperbilirubinemia of prematurity. *Pediatrics* 1969; 44: 162–167	Light intensity	Low birth weight babies at Providence Lying-In Hospital (n=96)
Glass P, Avery GB, Subramanian KN, et al. Effect of bright light in the hospital nursery of incidence of retinopathy of prematurity. *N Engl J Med* 1985; 313: 401–404	Light intensity (brightness)	Preterm infants at Georgetown University Hospital or Children's Hospital National Medical Center who weighed less than 2001 g and had a gestational age of less than 35 weeks at birth (n=228)

Study Design†	Outcomes	Findings	Comments on Study Validity
4	*Acremonium kiliense endophthalmitis*	Cases were more likely to have been operated on shortly after the ventilation system was turned on, indicating possible ventilatory source of infection	Case-control study design leaves room for unmeasured differences between groups
3, 4	Anxiety, annoyance with noise	There were no differences in state anxiety or annoyance due to noise between the noisy and quiet hours, controlling for the level of "trait" anxiety	1) Some of the analyses do not use paired data, limiting the study's power 2) There were two similar noise levels during the noisy and non-noisy hours
1	Self-reported pain	Subjects randomized to different forms of music did not differ in the level of pain they reported	1) Small sample size limits the power of the study; the differences seen are in the expected direction of lower pain with easy listening music and may be true differences 2) There are no data given about how the groups differ in other ways that may affect their pain; given the small sample size, this would confirm that the randomization "worked"
1	Frequency of waking, sleep-wake frequency, sleep-wake frequency variability	Neonates randomized to high frequency (blue) lightwaves have more waking, greater sleep-wake frequency, and greater variability in sleep-wake frequency than neonates experiencing low frequency (red) lightwaves	1) Excellent design: randomized trial 2) Generalizability to other racial groups and to ill neonates unknown
1	Serum bilirubin	Lower serum bilirubin in the group exposed to 90 footcandles compared to the group exposed to 10 footcandles; not as much effect as previous studies using higher intensity lights. No neurologic or visual problems at follow-up in the brighter light group	1) Randomized trial, excellent design 2) Only half of infants followed up for long-term outcomes, limits validity of those findings
1	Incidence/severity of retinopathy of prematurity	There was a higher incidence of retinopathy of prematurity in the group of infants who had been exposed to the brighter nursery lights, particularly in those with birth weights below 1000 g	Observational double-cohort study with sequential cohorts permits some unmeasured confounding; however, study populations are carefully characterized and stratified by birth weight

Bibliographic Information	Environmental Variable(s)	Study Population
Grauer T. Environmental lighting, behavioral state and hormonal response in the newborn. *Sch Inq Nurs Pract* 1989; 3: 53–66	Constant vs. intermittent light	Healthy newborns, setting not described (n=99)
Guzzetta CE. Effects of relaxation and music therapy on patients in a coronary care unit with presumptive acute myocardial infarction. *Heart Lung* 1989; 18: 609–616	Music	Patients in a coronary-care unit with the presumptive diagnosis of acute myocardial infarction (n=80)
Hahn JE, Jones MR, Waszkiewicz M. Renovation of a semi-private patient room. *Nurs Clinics of North America* 1995; 30(1): 97–115	Standard hospital room vs. remodeled room	Patients of the Geriatric Rehabilitation Unit at Rush Presbyterian–St. Luke's Medical Center (n=23)
Happ BA. The effect of point of care technology on the quality of patient care. *AMIA, Inc.* 1994; 183–187	Bedside computers	Geriatric patients from 5 medical/surgical nursing units in 3 acute care hospitals in the northeastern USA (n=90)
Harris CS, Bradley RJ, Titus SK. A comparison of the effects of hard rock and easy listening on the frequency of observed inappropriate behaviors: control of environmental antecedents in a large public area. *J Music Therapy* 1992; 29: 6–17	Hard rock vs. easy listening music	Adult male and female clients in a large public area at a state mental health hospital (n=13, 998)
Harwood RH, Ebrahim S. Long-term institutional residents: Does the environment affect outcomes? *J Royal College of Physicians of London* 1992; 26(2): 134–138	New and purpose-built wards with single and twin bedrooms and separate day and dining areas vs. refurbished maternity wards with four-bedded bays and separate day areas	Continuing care residents transferred to Royal London Hospital (n=95)
Hepner WR, Krause AC, Davis E. Retrolental fibroplasia and light. *Pediatrics* 1949; 3: 824–828	Exposure to light vs. shielding eyes with cotton pads and a stocking hood	Premature infants of 28–37 weeks' gestation and 1170–1350 gm birth weights at the Chicago Lying-In Hospital (n=5)

Study Design†	Outcomes	Findings	Comments on Study Validity
2	Salivary cortisol levels	Awake babies had rises in cortisol with intermittent light, sleeping babies had a fall in cortisol	Experimental trial with sequential assignment, good study design
1	Apical heart rates, peripheral temperatures	Music together with relaxation therapy resulted in a greater rise in peripheral temperatures but no difference in lower apical heart rates compared with relaxation therapy alone	Strong study design
4	Satisfaction with patient room environment including: bedside accessibility, closet accessibility, closet utility, nightstand accessibility, personal item storage, personalization of patient care storage, lighting, cleanliness, and appearance	Customer satisfaction rose significantly in all 10 areas in renovated rooms; e.g., in old room 100% rated closet accessibility poor or very poor, in new room 57% rated it good or very good	1) Weak study design 2) Small sample size 3) No comparison of patient groups before and after remodeling to examine for possibility of confounding
4b	Patient satisfaction with nursing care	Patients without bedside computers were more satisfied with their care than were those with the computers	No examination of differences in patient populations
4	Frequency of inappropriate behaviors	More inappropriate behavior was observed under conditions in which rock and rap music were played than when easy listening and country music were played	1) Although an observational study, the large number of subjects makes confounding unlikely 2) No controls for lyric content or rhythm variations
3	Deaths, changes in disability over 12 months recorded using Barthel Index and Clifton Assessment Procedure for the Elderly (CAPE), behavioral rating and cognitive assessment scales	New wards had no advantage: Patients' Barthel scores improved more on the refurbished wards (difference 2.5 points at 4 months, $p < .0005$); changes in CAPE scores and mortality rates were similar on the two types of wards	Strong study design with well-validated outcome measures
4b	Retrolental fibroplasia	Four of five infants developed retrolental fibroplasia	Very small study population. However, although control data were not presented, 80% incidence in the study group clearly rules out shielding as a preventive measure and therefore light exposure as the etiology

Bibliographic Information	Environmental Variable(s)	Study Population
Hilton BA. Noise in acute patient care areas. *Res in Nurs & Health* 1985; 8: 283–291	Noise level	Open-heart-surgery patients on pre- and postoperative wards and ICU, patients at a large general hospital, ICU and medical ward patients in a small teaching hospital, ICU patients in a small community hospital, all in a large metropolitan area in northwest Canada (n=25)
Humphreys H, Johnson EM, Warnock DW, et al. An outbreak of aspergillosis in a general ITU. *J Hospital Infection* 1991; 18(3): 167–177	False ceilings, no artificial ventilation, building work adjacent to intensive-therapy unit	Patients in the intensive-therapy unit at Bristol Royal Infirmary (n=229)
Jolly H, Molyneux P, Newell DJ. A controlled study of the effect of temperature on premature babies. *J Pediatr* 1962; 60(6): 889–894	Temperature	Premature infants at Plymouth Hospital, England, who required incubator nursing (n=214)
Kyriakides GK, Zinneman HH, Hall WH, et al. Immunologic monitoring and aspergillosis in renal transplant patients. *Am J Surgery* 1976; 131(2): 246–252	Ventilation system contaminated by bird droppings	Patients who had received renal allografts in the VA Hospital in Minneapolis, Minnesota (n=3)
Lamberg-Allardt C. Vitamin D intake, sunlight exposure and 25-Hydroxyvitamin D levels in the elderly during one year. *Ann Nutr and Metab* 1984; 28: 144–150	Exposure to outdoor sunlight	Three groups of elderly people: 1) long-stay geriatric patients, 2) old people's home occupants, 3) healthy ambulatory persons. A control group was of healthy younger persons (n=96)
Lidwell OM, Lowbury EJL, Whyte, et al. Infection and sepsis after operations for total hip or knee-joint replacement: influence of ultraclean air, prophylactic antibiotics and other factors. *J Hyg Camb* 1984, 505–529	Ultraclean air ventilation	Surgical patients from 19 hospitals in England, Scotland, and Sweden during 1975–80 (n=8000)

Study Design†	Outcomes	Findings	Comments on Study Validity
4	Patient-reported ability to sleep and patient satisfaction	Only the large hospital's ICU and recovery room recorded average sound levels above 60 db(A). On these units, patients perceived that noise interfered with rest and sleep, while on the other units, patients did not	Very small sample size limits power of study, and prevents adjustments of possible confounding factors
4	Infection by invasive aspergillosis	Over a five-month period, during construction work adjacent to the intensive-care unit, 6 (2.6%) of 229 patients were infected with *Aspergillus* species. After construction of a new intensive-care unit without false ceilings and with an artificial ventilation system, no further infection occurred	Observational study with historical controls design limits certainty about conclusions and permits confounding due to seasonal changes and other differences between locations or patient populations
1	Mortality, body temperature, vomiting, edema, days to regain weight, respiratory distress syndrome, jaundice, cerebral irritation	Babies in the cold group who were very low weight took longer to regain their birth weight than similar babies in the hot group; there was higher mortality for low birth weight babies in the cold than in the hot group	1) Many of the outcomes were subjectively recorded by unblinded nursery panel 2) Randomized controlled trial: strong study design
4	Infection with *Aspergillus fumigatus*	In six months, three cases of *Aspergillus fumigatus* infection were recognized. After replacement of a missing bird screen and repair of a malfunctioning fan in an air duct, no further cases occurred	Study limited by small sample size and observational study design with historical controls
4	Serum-OH-D concentrations	Serum-OH-D concentrations were lowest in group 1. This group also had lowest vitamin D intake (50% of RDA) and almost no outdoor sunlight exposure). The amount of sunlight exposure and vitamin D intake were both associated with serum-OH-D levels	Observational study of different groups permits confounding by other variables that may influence outcome, including vitamin D intake and other characteristics that determine where elderly patients live
4	Joint sepsis, major wound sepsis, pain	Lower incidence of joint and major wound sepsis among patients operated on in ultraclean air, no difference in pain	1) Confounding is possible given comparisons among different hospitals with different environmental conditions 2) There is no information about the reliability of subjective staff-assessed measures

Bibliographic Information	Environmental Variable(s)	Study Population
Loesin RGRAC. The effect of music on the pain of selected postoperative patients. *ANOPHI Papers* 1979: 1–10	Music administered postoperatively	Subjects undergoing gynecologic surgery at Silliman Hospital, Philippines (n=24)
Loo VG, Bertrand C, Dixon C., et al. Control of construction-associated nosocomial aspergillosis in an antiquated hematology unit. *Infect Control and Hosp Epidemiol* 1996, June 17(6): 360–364	Infection-control design features: high-efficiency particulate air (HEPA) filter air purifiers, application of copper-8-quinolinolate–formulated paint, replacement of perforated with nonperforated ceiling tiles, sealing of all windows, replacement of horizontal, dust-accumulating blinds with vinyl, opaque, roller shades, and systematic and regular cleaning of surfaces	Patients with leukemia or bone marrow transplants in a university tertiary-care center with a single designated hematology-oncology unit (n=36)
Mann NP, Haddow R, Stokes L, et al. Effect of night and day on preterm infants in a newborn nursery: randomized trial. *BMJ* 1986; 293: 1265–1267	Light intensity and noise level reduction in a "night and day" pattern nursery vs. continuous lighting and noise level nursery	Preterm (27–35 weeks) infants with no major neurological illnesses (n=41)
Melin L, Gotestam KG. The effects of rearranging ward routines on communication and eating behaviors of psychogeriatric patients. *J Appl Behav Anal* 1981; 14: 47–51	Furniture arrangement: chairs grouped around tables vs. against corridor walls, brighter lighting, and elimination of individual trays	Psychogeriatric ward patients at a large mental hospital, with dementia or schizophrenia (n=21)
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	Headset music chosen by patients	Emergency patients at University of Pittsburgh teaching hospital, undergoing laceration repair (n=38)
Miller CI, White R, Whitman TL, et al. The effects of cycled versus noncycled lighting on growth and development in preterm infants. *Infant Behav Dev* 1995; 18: 87–95	Cycled lighting NICU vs. noncycled lighting NICU	Preterm infants in neonatal intensive care units (n=41)
Miller HC, Behrle FC, Hagar DL, et al. The effect of high humidity on body temperature and oxygen consumption of newborn premature infants. *Pediatrics* 1961: 740–747	Relative humidity (low vs. high)	Premature infants at the University of Kansas Medical Center (n=23, 11)

Study Design†	Outcomes	Findings	Comments on Study Validity
1b[1]	Pain ratings	Musculoskeletal and verbal responses to pain, blood pressure, and pulse were lower in patients assigned to music	The small sample makes it difficult to generalize
4	*Aspergillus* infection measured by mycology cultures	The incidence density in the preconstruction period was 3.18 per 1000 days at risk. During construction activity the ID increased to 9.88 per 1000 days at risk. After implementation of infection-control measures, the ID decreased to 2.91 per 1000 days at risk	There is no comparison of different patient groups to address possibility of confounding
1	Time spent sleeping and eating and weight gain	Infants randomized to a night and day nursery where the intensity of light and noise was reduced from 7 p.m. to 7 a.m. spent longer sleeping and less time feeding and gained more weight than infants in a control nursery where the light was not reduced	1) Excellent design — randomized trial and additional stratification by degree of prematurity 2) Blinding not possible; may bias findings 3) Reliability and validity of reports of sleep and eating not tested
1	Eating behavior, communication (tactile and verbal contacts)	Improved eating behavior in group with altered furniture arrangement	1) Excellent study design, random assignment to experimental group 2) Excellent interrater reliability of outcome measure
1	Heart rate, blood pressure, respirations, state anxiety scale score, pain rating, and rating of helpfulness of music	Patients who listened to music they chose during laceration repair had less pain and similar anxiety levels to the control group	1) Excellent methods, randomized controlled trial 2) Small sample in one hospital limits generalizability to other populations
4	Weight gain, time to oral feeding, days spent on ventilator and on phototherapy, and motor coordination	Compared to infants in the noncycled lighting unit, infants assigned to the cycled lighting unit had a greater rate of weight gain, were able to be fed orally sooner, spent fewer days on the ventilator and on phototherapy, and displayed enhanced motor coordination	1) Small sample size 2) Observational study — higher initial Apgar scores in the cycled lighting group may partly account for differences 3) Differences between the two units besides the lighting were unmeasured
3	Body temperature, oxygen consumption	Increased humidity increased body temperature and did not change oxygen consumption	1) Small sample size limits generalizability 2) Study method fairly strong, observational study with paired data

Bibliographic Information	Environmental Variable(s)	Study Population
Moss VA. Music and the surgical patient. The effect of music on anxiety. *AORN Journal* 1988; 48(1): 64–69	Music	Adult patients admitted for elective arthroscopic surgery to be performed under general anesthesia (n=17)
Nordstrom K, Norback D, Akselsson. Effect of air humidification on the sick building syndrome and perceived indoor air quality in hospitals — a four-month longitudinal study. *Occup Environ Med* 1994; 51: 683–688	Humidity level	Hospital employees in four geriatric hospital units in southern Sweden (n=90)
Okken A, Blijham FW, et al. Effects of forced convection of heated air on insensible water loss and heat loss in preterm infants in incubators. *J Pediatr* 1982; 101: 108–112	Forced convection of heated air	Healthy preterm infants on incubators in University of Groningen Hospital, The Netherlands (n=20)
Parkin SF. The effect of ambient music upon the reactions of children undergoing dental treatment. *ASDC J Dent Child*: 430–432	Ambient music played for five minutes vs. no ambient music	Children about to undergo cavity preparation in the Children's Dentistry Department of the Dental Hospital at the University College London Dental School, England (n=25)
Pattison HM, Robertson CE. The effect of ward design on the well-being of post-operative patients. *J Adv Nursing* 1996; 23: 820–826	Long-open "Nightingale" ward vs. ward with bays of four beds each	Postoperative patients at Glenfield Hospital, Leicaster, England (n=64)
Pelosi P, Solca M, Ravagnan I, et al. Effects of heat and moisture exchangers on minute ventilation, ventilatory drive, and work of breathing during pressure-support ventilation in acute respiratory failure. *Crit Care Med* 1996; 24(7): 1184–1188	Gas conditioning in pressure-support ventilation using a heated hot water humidifier vs. using a heat and moisture exchanger	Patients in a university hospital ICU (n=14)

Study Design†	Outcomes	Findings	Comments on Study Validity
4b	Change in anxiety from pre- to post-operative period	Results indicated a significant decrease from preoperative to postoperative anxiety for patients who listened to music. No significant difference was found in the control group.	1) Used well-validated instruments 2) Experimental systematic alternative assignment makes it more likely that results are valid 3) Very small sample reduces generalizability to other patient populations and age groups
3b	Sensation of dryness, irritation, and static electricity	Air humidification up to a relative humidity of 40–45% decreases the perception of dry air and static electricity	Because the same employees were studied before and after the intervention, the improved outcomes are likely due to the intervention despite the lack of paired analysis
2	Insensible water loss, heat loss	Forced convection increased insensible water loss, evaporative heat loss, and total heat loss, and decreased nonevaporative heat loss	Strong study methods, experimental controlled trial with paired data
2	Observers' assessment of children's anxiety	There was a significant reduction of overt anxiety when in the visit with ambient music prior to the dental procedure compared with a control visit in which no music was played	1) Good reliability: Four independent observers were used for each child 2) Good study design: Each child served as his/her own control in this experimental study with paired data 3) Generalizability to other populations unknown
4	Patient evaluation of health care, patient evaluation of noise; quality of life in the hospital, including sleep, friendships, privacy, isolation, anxiety, and depression	The "Nightingale" ward was perceived as significantly noisier than the bay ward and noise levels were significantly correlated with anxiety scores. 75% of patients preferred the bay ward design	No adjustment for patient differences between wards
2	Minute ventilation, static intrinsic positive end-expiratory pressure, ventilatory drive and work of breathing	Insertion of heat and moisture exchangers induced a significant increase in minute ventilation, static intrinsic positive end-expiratory pressure, ventilatory drive, and work of breathing	1) Small sample size 2) Strong study design

Bibliographic Information	Environmental Variable(s)	Study Population
Peterson R, Knapp T, Rosen J, et al. The effects of furniture arrangement on the behavior of geriatric patients. *Behav Therapy* 1977; 8: 464–467	Patient-determined furniture arrangement with furniture along the walls of the room, vs. elliptical arrangement of chairs around a table vs. small groupings of tables and chairs	Geriatric patients in a state mental institution in Nevada (n=20–34)
Reynolds JD, Hardy RJ, Kennedy KA, et al. Lack of efficacy of light reduction in preventing retinopathy of prematurity. *N Engl J Med* 1998; 338(22): 1572–1576	Reduced visible light versus typical nursery lighting	Premature infants at high risk for retinopathy of prematurity, based on low birth weights and gestational ages, hospitalized in intensive-therapy units at one of three study sites (n=361)
Riegler J. Comparison of a reality orientation program for geriatric patients with and without music. *J Music Therapy* 1980; XVII(1): 26–33	Music	Geriatric patients undergoing reality orientation therapy at the Château de Notre Dame Nursing Home, New Orleans, Louisiana (n=8)
Salvati EA, Robinson RP, Zeno SM, et al. Infection rates after 3175 total hip and total knee replacements performed with and without a horizontal unidirectional filtered air-flow system. *J Bone Joint Surg Br* 1982; 64-A(4): 525–535	Horizontal unidirectional filtered air-flow ventilation system	Patients undergoing single-stage total hip replacement or total knee replacement at the Hospital for Special Surgery, New York (n=3175)
Sauer PJ, Huib DJ, Visser HK. Influence of variations in the ambient humidity on insensible water loss and thermoneutral environment of low birth weight infants. *Acta Paediatr Scand* 1984; 73: 615–619	Humidity level	Preterm infants gestational age 29–34 weeks, mixed low and appropriate weight for gestational age at Academic Hospital Rotterdam/Sophia Children's Hospital, The Netherlands (n=11)

Study Design†	Outcomes	Findings	Comments on Study Validity
2b	Observer assessed frequency of talking, sitting, moving, standing, lying, watching TV, manipulating objects, stereotypy, attending to nursing station, reading, touching, cooperative behavior, doing hair, and playing with games or toys	The experimental arrangement of small groupings of tables and chairs resulted in a higher prevalence of talking. Other behaviors were unchanged compared to the baseline of the chairs along the walls. The elliptical arrangement did not result in any behavioral changes	It is unclear whether the same group of patients was observed in all three conditions. If so, the validity is greater as unmeasured differences could not confound results
1	Retinopathy of prematurity	There was no significant difference between the incidence of retinopathy of prematurity in the group that received reduced light (54%) and the control group (58%)	Randomized controlled trial with blinding is an excellent design. Conclusions may not be generalizable to populations of infants at low risk of retinopathy of prematurity
1	Confusion, social withdrawal, and apathy	The control group remained at the same level across trials while the experimental group showed marked improvement	1) Very small sample size 2) Confounding possible as differences between patient groups were not examined
4	Postoperative infection rates	Patients operated on in the filtered laminar flow operating room had reduced infection rates after total hip replacement compared with those operated on in conventional operating rooms. However, patients undergoing knee replacement in the laminar flow room had higher infection rates	1) The variable of the laminar flow room was confounded by the position of the operating team and the wound relative to the air flow 2) The observational double-cohort study design permits confounding by unanticipated factors
2	Insensible water loss and heat loss	Evaporative water loss was 40% lower at higher humidity, while metabolic weight and body temperature were the same	Experimental study with paired data; methods increase likelihood of validity

Bibliographic Information	Environmental Variable(s)	Study Population
Sensakovic JW, Smith LG. Nosocomial ultraviolet keratoconjunctivitis. *Infection Control* 1982; 3(6): 475–476	Improperly hung ultraviolet light	Patients and visitors in an isolation room at Saint Michael's Medical Center, Newark, New Jersey (n=5)
Sherertz RJ, Belani A, Kramer BS, et al. Impact of air filtration on nosocomial *Aspergillus* infections. Unique risk of bone marrow transplant recipients. *American Journal of Medicine* 1987; 83(4): 709–718	HEPA filtration units with horizontal laminar flow	Bone marrow transplant recipients at the University of Florida College of Medicine (n=113)
Shirani KZ, McManus AT, Vaughn GM, et al. Effects of environment on infection in burn patients. *Arch Surg* 1986; 121: 31–36	Open intensive care ward vs. intensive care ward with separate bed enclosures with sinks in each enclosure	Burn patients treated in an intensive care ward (n=386)
Shiroiwa Y, Kamiya Y, Uchibori S, et al. Activity, cardiac and respiratory responses of blindfolded preterm infants in a neonatal intensive care unit. *Early Hum Dev* 1986; 14: 259–265	Reduction of environmental light by blindfolding using an eye mask and a black head-cap	Preterm low birth weight appropriate-for-dates infants in an NICU at Seirei Hamamatsu General Hospital, Japan, healthy except for low birth weights (n=10)
Silverman WA, Agate FJ, Fertig JW. A sequential trial of the nonthermal effect of atmospheric humidity on survival of premature infants. *Am J Dis Child:* 77–78	Moderate vs. high humidity level	Matched pairs of infants (n=362)
Silverman WA, Blanc WA. The effect of humidity on survival of newly born premature infants. *Pediatrics* 1957; 477–487	Moderate vs. high humidity level	Premature infants less than 120 hours old at Babies Hospital (Columbia), New York (n=324)

Study Design†	Outcomes	Findings	Comments on Study Validity
4	Bilateral conjunctivitis, erythema	All five people exposed to direct ultraviolet light developed keratoconjunctivitis. Three patients also developed skin erythema	Despite small sample size and historical controls, causal inference is strong due to unusual nature of outcome and and prior knowledge that this outcome can be caused by UV light
4	Nosocomial *Aspergillus* infections	14 (19%) of 74 bone marrow transplant recipients housed outside of a HEPA-filtered environment developed nosocomial *Aspergillus* infections vs. 0 of 39 cases in a HEPA-filtered environment	Observational study design and small samples limit certainty of findings
4	Infection and mortality	Burn patients in the separate bed enclosures had fewer infections and lower mortality rates than patients in the open unit	No testing of reliability and validity of documentation of some of the recording-sensitive measures of infection such as "symptomatic bacteriuria"
2	Activity level, respiratory rate, heart rate	Activity was less and respiratory rates were lower when infants were blindfolded than when not blindfolded	1) Experimental paired or within-subjects study design enhances validity 2) Small sample size limits generalizability 3) No information about the reliability of observers' assessment of activity from videotapes
1	Mortality rates	No significant difference in survival was detected under the two humidity conditions	Reasonably good study design: Infants were matched with respect to a number of clinical features (e.g., antibiotics, globulin, and feedings) and assigned randomly to one of the two conditions
4	Retractions (respiratory distress), mean respiratory rates, body temperature, mortality rates, proportions of sterile cultures or distribution of organisms cultured	Better survival at high than moderate humidity, body temperature was a little higher at high relative humidity, and there were no differences in other outcomes	Double-cohort observational study design permits confounding by unmeasured variables, although groups are similar in demographics, birth weight, cause of prematurity, and route and position of delivery

Bibliographic Information	Environmental Variable(s)	Study Population
Soutar RL, Wilson JA. Does hospital noise disturb patients? *BMJ* 1986; 292 – 305	Noise level	Subjects were patients in the general medical wards, acute admissions, and psychiatry wards (n=91)
Spaeth GL, Angell MF. Preference of ophthalmic patients for multi-bedded hospital rooms. *Arch Ophthal* 1968; 79: 362–365	Single vs. multi-bed patient rooms	Ophthalmologic patients at Wills Eye Hospital in Philadelphia (n=580)
Strauch C, Brandt S, Edwards-Beckett J. Implementation of a quiet hour: effect on noise levels and infant sleep states. *Neonatal Network* 1983; 12(3): 31–35	Quiet hour in last hour of each nursing shift vs. control period	Very low birth weight infants in a neonatal developmental unit at Children's Hospital in Columbus, Ohio (n not stated)
Sulyok E, Jequier, Ryser G. Effect of relative humidity on thermal balance of the newborn infant. *Biol Neonate* 1972; 21: 210–218	Relative humidity level	Healthy newborns on the first day of life at University Medical School, Lausanne, Switzerland (n=31)
Tideiksarr R, Feiner C, Maby J. Falls prevention: the efficacy of a bed alarm system in an acute-care setting. *Mt Sinai J Med* 1993; 60(6): 522–527	Bed alarm system	Geriatric patients with poor mobility due to acute medical or chronic neuromuscular conditions in an acute-care setting (n=70)

Study Design†	Outcomes	Findings	Comments on Study Validity
4[2]	Disturbance of patients' sleep due to noise as reported by patient	Of 91 patients interviewed, 39 claimed their sleep was unaltered in the hospital as compared with home, 28 slept worse in the hospital, and 24 slept better. Of the 28 who slept worse in hospital, 9 stated this was due to noise	1) Poor study design: There is no control group and no comparison of patients at different noise levels 2) Patient self-report of worse sleep due to noise is of unknown validity 3) There is no information about the characteristics of study subjects, making it difficult to generalize to other groups of patients
1	Patient satisfaction with type of room, preference for type of room	After discharge, 92% of patients reported a preference for multi-bed rooms, with no difference between those who had been admitted to single or multi-bed rooms.	Few differences between patient groups were examined, so other variables may confound the comparison
3	Infant behavior and sleep state (deep, light, drowsy/semidozing, quiet awake, active awake, and crying)	Fewer infants were crying during the quiet hour than the control period (2.4 vs. 14.3%), and more were in deep or light sleep (84.5 vs. 33.9%)	1) Repeated measures design allows each infant to serve as his or her own control; nonrandomized to quiet hour 2) No information about reliability and validity of observed state and behavior
4	Activity level, evaporative, dry, and total heat loss, skin temperature	Evaporative heat loss is greater in lower humidity conditions, dry heat loss is greater at higher humidity (80%), heat storage and temperature are higher, and the metabolic rate is minimal at 50%, and either increasing or decreasing humidity causes a rise in the metabolic rate	Triple-cohort observational study is nonrandomized and permits confounding by unmeasured differences among the groups
1	Bed falls	There was no statistically significant difference in falls between the experimental group and the control group (5 vs. 12, p=1.00). However, in the experimental group the utilization of mechanical restraints to guard against bed falls declined	1) Small sample size with consequent limited power to detect difference; falls were less than half in the experimental group without statistical significance being achieved 2) The difference in mechanical-restraint use between groups also may have minimized the observed effect of the alarm system

Bibliographic Information	Environmental Variable(s)	Study Population
Timko C. Physical characteristics of residential psychiatric and substance abuse programs: organizational determinants and patient outcomes. *American Journal of Community Psychology* 1996; 24(1): 173–192	Score on scale measuring a variety of physical and architectural features, including proximity to community, availability of resources, space, and design of furniture layout to promote social interaction, space for staff, outdoor areas, accessibility of facilities to those with disabilities or wheelchairs, safety features, and amount of space	Patients in inpatient, residential psychiatric and substance abuse treatment settings in six San Francisco Bay–area counties (n=94)
Topf M. Effects of personal control over hospital noise on sleep. *Res Nurs Health* 1992; 15: 19–28	Noise level and personal control over noise using a sound conditioner	Healthy women volunteers, with no sleep or hearing problems, in a sleep lab (n=105)
Topf M. Noise-induced stress in hospital patients: coping and nonauditory health outcomes. *J Hum Stress* 1985: 125–134	Noise level and personal control over noise	Volunteer male surgery patients in a large metropolitan VA hospital (n=150)
Topf M. Stress effects of personal control over hospital noise. *Behav Med* 1992; 18: 84–94	Noise level, personal control over noise	Women volunteers paid to participate, average age 35, level of education 17 years (U of Colorado) (n=105)
Topf M, Davis JE. Critical care unit noise and rapid eye movement (REM) sleep. *Heart Lung* 1993; 22(3): 252–258	Noise level	Healthy women volunteers with no hearing or sleep problems in a sleep lab (n=105)

Study Design†	Outcomes	Findings	Comments on Study Validity
4	Successful completion of program, discharge to independent living and paid jobs	Programs with more physical amenities had patients who were more likely to successfully complete the program and be discharged to independent living situations and paid jobs. Programs with more social-recreational and prosthetic aids, space, and access to community resources also had better patient outcomes	Observational study design permits confounding by other factors about patients or facilities that may influence outcomes
1	20 measures of sleep, including 19 physiologic (including sleep efficiency, minutes and percent of time in bed, awake, asleep, in each stage of sleep, latencies to each stage, number of stage shifts, intrasleep awakenings, REM periods) and one self-report measure	Noise levels characteristic of critical care units caused poorer sleep but personal control using a sound conditioner had no effect	1) Excellent design (randomized trial) 2) Generalizability from volunteers in a sleep lab to critical care unit patients is questionable
1	Coping, i.e., degree of control exercised over noise, self-ratings of recovery, time out of bed	Personal control over noise resulted in more time out of bed but no difference in self-ratings of recovery	1) Randomized trial: good study design for portion of study analyzing effect of personal control of noise, comparable groups 2) Outcome measure with good internal consistency and concurrent validity for one part of the study
1	Sensitivity to noise, subjective stress, exercised control over noise	Noise is associated with subjective but not physiological stress; personal control over sound using a sound conditioner did not affect stress	1) Randomized trial: good study design for portion of study examining personal control of noise 2) Carefully designed measures of tested internal consistency and controls for social desirability 3) Volunteers may not be generalizable to patients
1	REM activity, REM density, and REM duration	Subjects in the noise condition showed poorer REM sleep on 7 of the 10 measures	Generalization of results to critical care unit patients is limited because of use of laboratory subjects

Bibliographic Information	Environmental Variable(s)	Study Population
Ulrich RS. View through a window may influence recovery from surgery. *Science* 1984; 224: 420–421	Natural vs. built view in a surgical ward	Cholecystectomy patients (n=46)
Walther-Larsen S, Diemar V, Valentin N. Music during regional anesthesia. *Reg Anesth* 1988; 13(2): 69–71	Music during surgery	Patients over age 15 undergoing orthopedic or plastic surgical operations under regional anesthesia, at Gentofte Hospital of the University of Copenhagen, Hellerup, Denmark (n=64)
Williamson J. The effects of ocean sounds on sleep after coronary artery bypass graft surgery. *Am J Crit Care* 1992; 1: 91–97	Ocean sounds produced by a sound simulator	Postoperative patients who had undergone first-time coronary artery bypass surgery, Huntsville Hospital, Alabama, a large public hospital (n=60)
Wilmott M. The effect of a vinyl floor surface and carpeted floor surface upon walking in elderly hospital in-patients. *Age and Ageing* 1986; 15: 119–120	Vinyl floor vs. carpeted floor	Elderly hospital patients of mean age 76.05 years (n=58)
Wilson LM. Intensive care delirium. *Arch Intern Med* 1972; 130: 225–226	Presence of windows in an intensive care unit	Postoperative major surgical patients requiring general anesthesia (n=100)

Study Design†	Outcomes	Findings	Comments on Study Validity
4	Length of hospital stay, negative evaluative comments in nurses' notes, amount of potent analgesics taken	Patients assigned to rooms with window views of a natural setting had shorter postoperative hospital stays, received fewer negative evaluative comments in nurses' notes, and took fewer potent analgesics than patients in similar rooms with windows facing a brick wall	1) One hospital setting and small sample size — issues of generalizability 2) Unmeasured differences between patients possible (including indication for cholecystectomy, morbid illness, physiologic severity of illness, and initial pain levels) 3) Built view closest to nursing station — there may be unmeasured differences such as more noise in the built view portion
1	Requirement for sedatives, anxiety during surgery	Fewer patients in the music group than in the nonmusic group needed sedatives (4 of 32, 13%, versus 14 of 32, 44%) although a significantly higher proportion of patients in the music group recalled feeling anxious during surgery	Strong study design
1b[3]	Sleep questionnaire, sleep scores	Group receiving ocean sounds perceived that they had slept better than the control group, and were awake less during the night, returned to sleep more quickly, and had higher sleep quality and total sleep scores. There was no difference in falling asleep scores	Experimental controlled trial with systematic assignment, good method
2	Walking efficiency and confidence were defined by gait speed and step length	Mean gait speed and step length were significantly greater on carpet than on vinyl. Patients expressed fear of walking on vinyl, none on carpet. In almost 25% of cases (14 patients), step length was 30% greater or more	Paired study design supports validity
4	Delirium and depression	Over twice as many episodes of organic delirium were seen in the intensive care unit without windows as in the unit with windows	1) Only one unit with or without windows studied — units may differ in other ways that affect patient outcomes. 2) No risk adjustment — observational study. Patients in two units may differ in unmeasured variables

Bibliographic Information	Environmental Variable(s)	Study Population
Wolff PH, Matsumiya Y, Abroms IF, et al. The effect of white noise on the somatosensory evoked response in sleeping newborn infants. *Electroencephalogr Clin Neurophysiol* 1974; 37: 269–274	White noise delivered by speakers on either side of infant's head	Full-term, normal birth weight neonates on the third or fourth day after delivery at Children's Hospital, Boston (n=21)
Yeh TF, Voora S, Lilien D, et al. Oxygen consumption and insensible water loss in premature infants in single- versus double-walled incubators. *J Pediatr* 1980; 97: 967–971	Single- vs. double-walled incubators	Premature infants appropriate for dates, gestational age 31–34 weeks, age 4–15 days old, at Cook County Children's Hospital (n=10)
Zahr LK, Balian S. Responses of premature infants to routine nursing interventions and noise in the NICU. *Nurs Res* 1995; 44: 179–185	Noise events	Premature infants in the NICU, 23–37 weeks of gestational age, 480–1930 g, at three large university hospitals in California and in Beirut, Lebanon (n=55)
Zimmerman LM, Pierson MA, Marker J. Effects of music on patient anxiety in coronary care units. *Heart Lung* 1988; 17: 560–566	Relaxation-type music with suggestion, synthetic silence with suggestion vs. control group	Patients with suspected myocardial infarction admitted to three CCUs in the Midwest (n=75)

Study Design†	Outcomes	Findings	Comments on Study Validity
2	Somatosensory-evoked response	White noise enhanced the amplitude and prolonged the latency of the late components of the somatosensory-evoked response in sleeping newborns	1) Experimental controlled trial, within-subjects paired data, enhances study validity 2) Small sample size limits generalizability
2	Oxygen consumption and insensible water loss	The double-walled-incubator infants had lower insensible water loss and lower oxygen consumption, with a net caloric saving of 11 kcal/kg/day	1) Small sample size limits generalizability 2) Experimental controlled trial with paired within-subjects data enhances validity
3b	Heart rate, respiratory rate, oxygen saturation, sleep and wake states	Noise resulted in fall in oxygen saturation, rise in heart rate, and rise in respiratory rate in 12–18% of infants. 78% of infants changed their behavioral state in response to noise, usually from sleep state to fussy/crying state	Group-level anaysis of data before and after limits power of study; paired data were not analyzed for statistical significance
1	State and trait anxiety, blood pressure, heart rate, digital skin temperature	No difference in state anxiety, heart rate, blood pressure, or skin temperature	(1) Randomized clinical trial enhances confidence in validity (2) Outcome measures tested for reliability and validity

APPENDIX C
Ratings of Suggestions for Studies of the Effect of the Built Healthcare Environment on Outcomes

Votes [1]	Patient Group	Setting	Features	Outcome
Adult Acute Care				
2	Adult acute care	Patient room Inpatient unit	Place for family to stay inside the room or out of it	↓ Length of stay ↓ Medication use ↓ Symptoms ↑ Functioning ↑ Family coping with stress
4	Patients undergoing diagnostic testing (e.g., X-ray/ mammography/ MRI)	Areas where diagnoses are made at point of testing	How much setting allows education/understanding Outpatient vs. inpatient Guidelines Space away from technology Change how to provide increased privacy Separate patients with different results, cancer diagnoses	↓ Anxiety about procedure ↑ Cognition/understanding of what was said ↑ Adherence to follow-up care ↓ MRI: claustrophobia ↓ Redundancy
2	Acute short-stay, high-volume day surgery or procedure patients (e.g., cardiac catheterization) pre-procedure	Pre-procedure waiting area Pre-procedure room environment	Visual design Privacy	↓ Admission for complications ↓ Stress ↓ Cardiac: arrhythmias
Adult Acute Care (Critical Care)				
5	Non-comatose intensive-care patients	Intensive-care unit	Exterior windows Exposure to sunlight Control activity around patient at sleep time Nursing station Color reflectivity using lighting or gel on fixture Lighting intensity/color Privacy	↓ "ICU-itis" disorientation ↓ Sleep psychosis ↓Sundowning ↑ Diagnosis accuracy ↓ Length of stay ↑ Patient satisfaction ↓ Recovery time

[1] How many focus group participants submitted this as one of their two choices

[2] Criteria were developed by a focus group of The Center of Health Design's Research Committee. Ratings were assigned by the investigators.

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	3	3	3	2.5	3	2	2	1.5	1.5	**24.5**
2	2	2	2	1.5	2	2	2	2	2	**19.5**
2	3	3	3	2	3	3	1	2	2.5	**24.5**
3	2.5	3	3	3	3	3	2	2	1.5	**24**

[3] A total score is provided summing up all criteria; this is not meant to support its use as a summary score. The reader may wish to weigh some criteria more than others.

RATING LEGEND

1 = lowest, 3 = highest, ? = insufficient information

Votes [1]	Patient Group	Setting	Features	Outcome
2	Cardiac patients/admissions with myocardial infarction	Critical-care unit	Noise Disruptions (blood pressure cuff) Light and lighting Discomfort of monitor on chest IV pole to push to bathroom Room for family to be with patient	↓ Fear/anxiety ↑ Understanding ↓ Blood pressure ↓ Heart rate ↑ Stability (cardiac) indicator ↓ Intake of various drugs ↑ Quality indicator of visits from family
4	Critical care various diagnoses	Acute-care hospital Intensive-care unit	Privacy Music/audio Lighting Color Bathroom facility to accommodate those who request more than a bedpan Remove fluorescent light Minimize sounds of machines/alarms Keep door closed Carpet floor Align bed to see outside the window Block off glass doors for privacy Add pictures on walls Convert two-bed rooms to singles Window behind head or to the side so patient can see change of day to night	↑ Comfort ↓ Length of stay ↓ Days in intensive-care unit ↑ Six-month survival ↓ Circadian rhythm and ICU psychosis ↑ Patient's retrospective memory of the incident
Surgery and Procedures				
2	General adult day surgery	Outpatient recovery room	Color Location of technology Plants, carpets, smells, sounds Touch by staff Lighting Home features, furniture, seating	↓ Inpatient admissions ↓ Readmissions ↓ Recovery time ↓ Complications ↑ Patient satisfaction

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	2.5	3	2	2	2	2	2.5	2.5	2.5	**24**
3	3	3	3	3	3	3	2	2	2	**27**
2	2	3	2	2	3	2	3	3	3	**25**

Votes [1]	Patient Group	Setting	Features	Outcome
1	Cardiac angiography	Acute-care hospital	Control over light, temperature, and noise	↓ Stress ↓ Anxiety ↑ Wellness
8	Cardiac surgery postoperative patients	Surgical intensive-care unit	Improved visual design of place for family to sit (e.g., alcove with bench and mural of nature scene) Reducing noise level Painting ceiling tiles above bed Giving patients something to see when they are awake	↓ Length of stay ↑ Patient satisfaction ↑ Mobility ↓ Extubation time ↓ Complications
1	Baby boomers nonelective surgery Patient and care partner	Ambulatory surgery facility Waiting and registration area	Music, TV, video, telecomm, vistas Sensitivity of staff Flexible-use space, furniture, electronics Information and education regarding care	↓ Stress during waiting period ↑ Satisfaction regarding information and training
Ambulatory Adult Operations			Increased flexibility of environment ↑ Choice of privacy Variety of lighting Convenient access	↑ Access ↑ Comfort ↑ Compliance ↑ Family and visitor participation ↓ Stress
1	All adult and ambulatory patients	Hospital lobby		
1	All who seek outpatient treatment	Outpatient registration	All environmental features that encourage and facilitate ease of access—wayfinding, visibility, privacy, comfort, lighting, clearer signage	↓ Rate at which treatment is sought from time condition is first realized
1	Well adult outpatients	MD office: arrival, registration, waiting, exams	Privacy at registration Sufficient waiting for patients to be separate Provision for distraction Privacy, but ability to know where physician is in exam room Privacy re billing on exit	↑ Interest in returning ↓ Stress

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
2	2	3	2	2	3	2	3	3	3	**25**
2	3	3	3	2	3	3	1	2	2.5	**24.5**
2	2	1	1	1	3	3	3	3	3	**22**
1	2	3	1	2	2	3	2	1.5	2.5	**20**
1	2	2	2	3	2.5	3	2	2	3	**22.5**
1	1	3	3	3	3	2.5	2	2	2.5	**23**

Votes [1]	Patient Group	Setting	Features	Outcome
1	Ambulatory diabetic	The home as site for self-care	Access to entrance Accessibility of bathrooms, cabinets, kitchen appliances Use of computers	↑ Recovery
Chronically Ill Adults in Residential Facilities			(Not specified)	↑ Healing
1	Adult chronic care	Care unit where patients reside for long periods		
1	Patients with multiple sclerosis (age 20–30)	Long-term care	Mechanical devices to abet communication and mobility	↓ Anxiety ↑ Function ↑ Wellness ↑ Feeling of usefulness
4	Rehabilitation	Rehabilitation facility	Access to nature Space available for "normalizing" environment Dining/activity areas	↑ Patient satisfaction ↑ Reports of evaluation of care ↓ Length of stay ↑ Well-being ↑ Relation of patient evaluation to their expectations
1	Traumatic brain injury	Rehabilitation facility	Room design to enhance mobility, sociability, and the recovery process ↑ Patient's control of his/her environment	↑ Functionality measured by Functional Independence Measure ↓ Length of stay
2	Palliative care, terminally ill patients	Hospice or inpatient units for terminally ill patients	View/connection with outdoors, world outside	↑ "Dying with dignity"

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
2	2	3	2	1	2	1	2	2	2	**19**
3	?	?	2	?	?	?	?	?	?	**5**
3	3	2	3	2	2	2.5	3	3	3	**26.5**
3	2	3	2	3	3	2.5	2	2	2	**24.5**
3	3	3	3	2	3	3	2.5	2.5	2.5	**27.5**
3	3	1	3	1.5	3	2.5	2	2	2	**23**

Votes [1]	Patient Group	Setting	Features	Outcome
2	Cognitive impairment/ functionally independent	Long-term care	Control of temperature, lighting Access to toilet Access to outside Access to emergency exits Movement, e.g., surfaces, thresholds, sizes of door frames, weight of furniture, automatic doors, elevators vs. stairs	↑ Outcomes that are most likely to have an interrelationship with the physical environment and are most meaningful in healthcare ↑ Relief of suffering ↑ Familiarity ↑ Caring communications ↑ Independence
Elderly Long-Term Care			Provision for history recall Features to increase memory Access to nature Provision for family Auditory environment (outdoor setting, forest sounds, transporting sounds) Promote staff healing environment for themselves Flexibility of environment to accommodate increasing level of care needed so patient does not need to move, e.g., mobile home on campus Bathroom design Access for walker space Access to more functions	↓ Cost ↓ Depression ↑ Independence (cook/care for themselves) ↑ Quality of life ↑ Social interaction ↑ Ambulation ↑ Continence ↓ Medication use ↓ Bedsores ↑ Acceptability of patients to other patients ↑ Happiness ↑ Interaction at dining table ↑ Patient satisfaction ↑ Patient acceptance ↑ Patient self-esteem
10	Elderly in long-term care	Long-term care facility		
1	Elderly	Long-term care patient rooms	Color Gardens/patios ↓ Noise Design with residential hierarchy of public to private Homelike, familiar attributes	↓ Length of stay ↓ Medication

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	3	3	3	1.5	3	3	3	1.5	1.5	**25.5**
3	3	3	3	2	3	3	2.5	3	2.5	**28**
3	2.5	3	2.5	2	3	2.5	2	2.5	2.5	**25.5**

Votes [1]	Patient Group	Setting	Features	Outcome
2	Elderly frail	Assisted living and senior living facility	Lighting Washroom access Upgrade the bathroom system beyond ADA requirements Carpeting/obstacles Space to transfer to toilet Toilet height Space to hang clothing in bathroom Shelves Privacy	↑ Convenience ↑ Function ↓ Length of stay ↑ Orientation ↓ Agitation ↓ Falls ↑ Autonomy
1	Frail non-demented elderly	Long-term facility	Humanization, e.g., playgrounds Environment that facilitates visiting with people Connection with people, e.g., Internet	↑ Patient satisfaction with environment ↑ Patient happiness, anxiety ↓ Family stress, fear ↑ Patient dignity
1	Elderly cognitively intact/frail assistance with 2–4 ADLs	Long-term care common spaces	Walking distances that are reasonable to common spaces form units Smaller, domestic scale Residential amenities Home setting Area for intergenerational interactivity (kids, plants, animals) Flexibility of layout for different settings	↑ Independence ↑ Socialization ↑ Quality of life ↑ Safety ↑ Happiness, well-being ↑ Fulfilled life
1	Elderly after late middle age with life-threatening incapacitating diagnosis	Long-term care	Accessibility Independence Comfort: color, temperature, etc. Activities Safety	↑ Quality of life ↑ Hope ↑ Enjoyment
1	Alzheimer's (age 70 +)	Long-term care modules of +/- 42 beds	Room configuration Common area design Eating area	↑ Sociability ↓ Stress

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	3	3	2.5	3	3	3	3	2	2	**27.5**
3	3	3	3	2	3	3	2	2	3	**27**
3	3	3	2.5	2	3	3	2.5	2	2.5	**26.5**
3	2.5	3	3	2	3	2.5	3	3	3	**28**
3	2	2	2	2	3	2.5	2.5	1	3	**23**

Votes [1]	Patient Group	Setting	Features	Outcome
2	Alzheimer's/ dementia (especially in palliative care)	Not specified	Gardens as rooms Courtyard with rails Gardens as private area for family Acoustics/water, wind chimes Landscaping Lighting	↑ Comfort/relief ↓ Aggression ↓ Agitation ↓ Conflict ↓ Depression ↑ Family involvement ↓ Medication for aggression
1	Elderly/ dementia (up to Alzheimer's) and some physical limitations	Nursing home	Homelike atmosphere with playground for kids Cooking activity to promote family to come in and involve themselves with resident Make it extension of home	↑ Positive distraction ↑ Family involved ↑ Satisfaction ↑ Interest
1	Elderly cognitively impaired, some ADL impairment Medically stable	Nursing unit	Wayfinding Seating Ability to get up Doors—ability to operate	↑ Independence on Activity of Daily Living measures or by observation
1	Elderly cognitively impaired/ frail/stroke	Long-term care	Scale adjustment in room Ease of movement Stimulate by noise, vision, interaction Toilet rooms: soft material and usable toiletries	↑ Independence ↓ Infection control and odor ↑ Willingness to leave the room and live + happiness
Elderly Acute Care			Special space for this type of patient cluster Space for family and patient interaction Marking safety features Easy access Outdoor view Educational opportunities and space for families	↑ Orientation ↓ Injury ↑ Activities of daily living; functional status ↑ Self-care ability ↓ Length of stay ↓ Costs
5	Acutely ill elderly with reduced mental status	Acute-care hospital		

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	3	3	3	2	3	3	2	1	2	**25**
3	2	3	3	3	3	3	2	1	3	**26**
3	3	3	2	2	3	3	2.5	3	2.5	**27**
3	3	3	2	2	3	2.5	2.5	2	2.5	**25.5**
3	3	3	3	3	3	3	2.5	2	2.5	**28**

Votes [1]	Patient Group	Setting	Features	Outcome
3	Elderly surgical	Surgical intensive-care unit	↓ Noise ↓ Artificial light Provide views to natural setting (sky, trees, or garden) from patient bed	↓ Intensive-care unit psychosis ↓ Length of stay ↑ Willingness to undergo surgery and be in surgical intensive-care unit again ↓ Mortality ↑ Six-month survival
Elderly Outpatient			Location where services are provided to the public Increased accessibility Convenience	↑ Patient satisfaction ↑ Accessibility ↑ Convenience ↑ Speed of getting in and out
2	Elderly outpatient	Ambulatory-care center		
1	Elderly outpatient	Outpatient clinic	Garden access view from waiting room Social activities	↑ Survival ↑ Level of physical function ↓ Need for pain medication
1	Elderly, frail; cognitively stable	Ambulatory treatment	Seating Access to bathrooms Layout of bathrooms Temperature Access to food	↓ Agitation
1	Elderly outpatient losing mental abilities; unable to decide what is right to do	Physician's office consultation	Elimination of "intimidating" desk and degrees on wall	↑ Positive choice
Elderly (Other)			Color Gardens/patios ↓ Noise Design with residential hierarchy of public to private	↓ Aggression ↓ Medication ↑ Other standard measures ↑ Quality of life
1	Geriatric psychiatric	Inpatient		

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	3	3	3	3	3	3	2.5	2	2.5	**28**
2	1.5	3	2	2.5	3	3	3	2.5	3	**25.5**
2	3	3	2	2	3	1	2	2	2.5	**22.5**
2	2	2	2	2	3	3	2	2	2.5	**22.5**
3	1	2	2	2	3	?	3	3	3	**22**
3	3	3	2	2.5	3	3	2.5	2	2.5	**26.5**

Votes [1]	Patient Group	Setting	Features	Outcome
Cancer Patients			Amenities Gardens/nature "Healing environment"	↑ Survival ↑ Response rate ↑ Satisfaction with environment for patient/family
7	Cancer patient undergoing radiation/ chemotherapy	Radiation therapy and chemotherapy areas Area of in/out intake screening Parking		
3	Bone marrow transplantation	Oncology area	Degree of isolation Facilitation of social support "Prison" feeling Sensory deprivation Change of visual environment Control over environment	↓ Graft vs. host disease ↓ Depression ↓ Anxiety ↓ Mortality ↑ Psychological and physical functioning
1	Lung cancer	Acute care	Not specified	↓ Length of stay ↑ Desire to go home ↑ Personal growth
1	Esophageal or other cancer patients undergoing attempted curative therapy	Pre-op Patient room	Close distance to RNs Visual access to corridor Conducive to well-being Home atmosphere: colors, beds, bed linens w/colors, patterned upholstery, sharp containers out of sight, attractive prints on walls, space for cards, biological waste out of sight Pleasant space to sit in corridor Bigger closet Two high wingback chairs Place for family to sleep Consider impairment Space for equipment	↓ Anxiety ↓ Pain ↓ Length of stay ↑ Healing ↑ Quality of life ↑ Privacy ↑ Comfort in facility

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
2.5	3	2	3	3	3	2	2.5	2.5	2.5	**26**
3	3	1	2.5	2	3	2.5	3	3	3	**26**
3	2.5	2.5	?	?	?	?	?	?	?	**8**
3	3	3	3	3	3	2	2.5	2.5	3	**28**

Votes [1]	Patient Group	Setting	Features	Outcome
1	Adult or adolescent cancer outpatient	Private or group setting Outpatient ambulatory setting	Presence of plants, aquariums, living things (butterflies, e.g.) Control for subdued lighting, full spectrum and specular natural sounds in three dimensions Acoustic control Aromatherapy controls Alternate seating/wing choices	↑ Efficacy of chemotherapy ↓ Amount of chemotherapy ↓ Drugs/cost ↓ Duration of treatment required (# visits total time) ↑ Clinical outcome measures
Adolescents			Control of interactions with patients, staff, visitors Lounges for small groups Interaction, entertainment areas Pain medication request Stress Length of stay Parent participation	↑ Self-esteem — feeling of support through progressive process ↑ Visual or physical access to social space
2	Adolescent inpatients, terminal; progression long/short	Acute care Therapeutic intervention Step-down intensive-care unit		
Children			Access to outdoor play	↓ Pain medication request ↓ Stress ↓ Length of stay ↓ Pain ↑ Parent participation
4	Pediatrics	Inpatient		
1	Pediatrics oncology	Patient room	Control over: temperature, light, sound "Personalization" with personal belongings Color "Homelike," residential-type design features Room-size capability Parent accommodations, i.e., lounge, showers, kitchen	↑ Comfort ↑ Psychological and physical peacefulness

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	2.5	1.5	3	2	3	2	3	3	3	**26**
3	2	2	3	2	3	3	2	2	2	**24**
3	2	3	3	3	3	3	3	3	2.5	**28.5**
3	2.5	3	3	2	3	3	3	3	2.5	**28**

Votes [1]	Patient Group	Setting	Features	Outcome
2	Pediatric inpatient with chronic or terminal illness	Intensive-care unit Inpatient unit	Give back childhood ↑ Control ↓ Isolation ↓ Removed from peers "Star Bright" virtual connection to others (Internet) ↑ Family, parents, and siblings (offer environment for them) ↑ Feature that are "fun"	↑ Self-esteem ↑ Recovery ↑ Control ↑ Empowerment ↓ Family stress
1	Schoolchildren who are sick and are staying home from school	Their residences	Increased degree of personal privacy	↑ Rate of recovery until return to school
1	Critically ill children	Pediatric intensive-care unit	Sleeping facility for parents Transition room for going home to do care Massage prescription Reduction of noise Conference room so child does not hear parent/provider discussions Family sleeping area	↓ Fear ↑ Sleep ↓ Anxiety ↑ Child's psychological adjustment ↓ Recovery time ↑ Recovery rate ↓ Length of stay
6	Neonates	Neonatal intensive-care unit	Individual rooms for each baby with parents Sleeping facility for parents Lighting, sound Music in crib or in room Transition room for going home to do care Massage prescription Facilitate contact/touch between parent and baby Privacy for parents regarding poor prognosis	↑ Relax kids, parents, staff ↑ Weight gain and faster in neonatal intensive-care unit ↓ Abuse ↑ Bonding ↓ Length of stay

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	3	3	3	3	3	2	3	3	3	**29**
2	2	1	2	1	1	1	2	1	1	**14**
3	2.5	2	3	3	3	2	2	2	2	**24.5**
3	2	1	3	2	3	2	3	2.5	2.5	**24**

Votes [1]	Patient Group	Setting	Features	Outcome
Emergency			Security systems Fireplace Waterfall Fountain Privacy Control over TV More isolation from other patients Separation of levels of care Don't roll patients through ER waiting room Access to patients for family Privacy of conversation Individual rooms Quiet space for teaching patients before leaving ER Specific ER section — more space for wheelchairs/geriatric "Geri" assessment area in ER Place for family/advocate Lighting Compare design at various sites	↓ Stress/anxiety ↓ Violence ↓ Parental and family anxiety ↓ Anxiety in ER ↑ Knowledge, understanding of diagnosis ↑ Medication doses being taken correctly ↑ Follow-up ↑ Efficiency of patient flow ↓ Cost/case ↑ Staff-patient ratios Clinical outcome of similar patient ↑ Patient satisfaction with experience
9	Emergency patients	ER rooms ER waiting room		
1	Pregnant women	Birthing rooms	Patient control of environment, light, temperature, privacy Ability for rooming in Size of room Configuration of room Introduction of positive distraction: access to nature, music, bathing, A/V equipment	↓ Anxiety ↑ Quality of experience ↑ Wellness of child ↑ Ability of care partners to participate ↓ Length of delivery

Patient Vulnerability [2]	Importance of Outcome	Generalizability to Other Populations	Public Appeal	Administrator Appeal	Practitioner Resource	Directness of Environmental Effect	Rigor of Study	Feasibility of Research	Feasibility of Intervention	Total Score [3]
3	2.5	3	3	2	3	3	2	2	2	**25.5**
2	2	2	3	2	3	2.5	3	3	3	**25.5**

APPENDIX D
Proposed Research Plan Timetable

	1998	1999	2000	2001	2002–2005	2006
1. Update status report						
2. Continue/expand literature search						
3. Focus groups/consensus panels (patient group specific): Which features could be changed to produce best results?						
4. Proposal for pilot studies						
5. Pilot studies (one group, one feature)						
6. Develop proposal						
7. Experimental study						
8. Report and disseminate study results						