Health Impacts of Healing Environments

A review of evidence for benefits of nature, daylight, fresh air, and quiet in healthcare settings

Agnes E. van den Berg

The Architecture of Hospitals

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Preface

Evidence-based design is a hot topic. Undeniably, architecture has a profound impact on the way people feel, and architects have been all too eager to underline the healing influences of their work. For a while, some of them even dressed like physicians to highlight the healing powers of their architectural designs. When it comes to substantiating these claims, however, architects and town planners usually had little to offer. Fortunately, times have changed since then. Leading experts in evidence-based design now maintain that the effects of architecture on health and healing can be scientifically demonstrated.

For obvious reasons, the hospital plays a dominant role in evidence-based design. If architecture can promote healing, then hospitals are the places where such effects are most urgently needed. As such, it is no coincidence that evidence-based medicine provided the inspiration for this new area of research. As yet, however, evidence-based design does not play a dominant role in the architecture of hospitals. One of the reasons for this lack of engagement is that healthcare decision makers have questioned the quality of the available evidence for health impacts of healing environments. Thus, if evidence-based design is going to revolutionize the architecture of hospitals, it will first have to bridge the gap between rigorous medical standards for scientific research, and what is accepted as evidence in the social sciences.

The present publication was written to stimulate and deepen the discussion on evidence-based design during the international conference 'The Architecture of Hospitals', to be held in Groningen, April 13-15, 2005. It provides a critical review of research on health benefits of four classical elements of healing environments: nature, daylight, fresh air, and quiet. The review combines previous surveys with new data, and offers a broad overview of relevant themes and topics. The outcomes suggest that there is sound evidence for the health impacts of healing environments which can no longer be ignored. How this will affect future research and in what way it will enrich the architecture of hospitals will be among the fundamental issues that evidence-based design will have to address in the near future.

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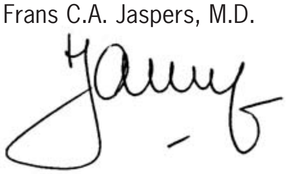


Member of the Executive Board, University Medical Center Groningen

1. Introduction

Conventional healthcare settings are rarely therapeutic and frequently increase levels of stress in patients, family and staff. Indeed, many people have had some of their worst experiences with buildings in clinics and hospitals. But there are signs that things are changing. The field of healthcare design is currently undergoing an exciting transformation that will significantly change the appearance of our hospitals. More and more healthcare administrators and medical professionals are becoming aware of the need to create *healing environments* that support the needs of patients, family and staff. The key factor motivating this awareness has been growing scientific evidence that the physical environment in which medical care is provided has an impact on health and well-being.

Nature and ‘natural elements’, such as daylight, fresh air, and quiet, have traditionally played an important role in the design of healing environments. The use of nature in healthcare settings can be traced as far back as the Asclepieia of ancient Greece. More recently, long-standing notions of the healing powers of nature have received support from rigorous scientific research. Among other things, this research has shown that contact with nature and natural elements can reduce anxiety, lower blood pressure, and lessen pain (Ulrich, 1999).

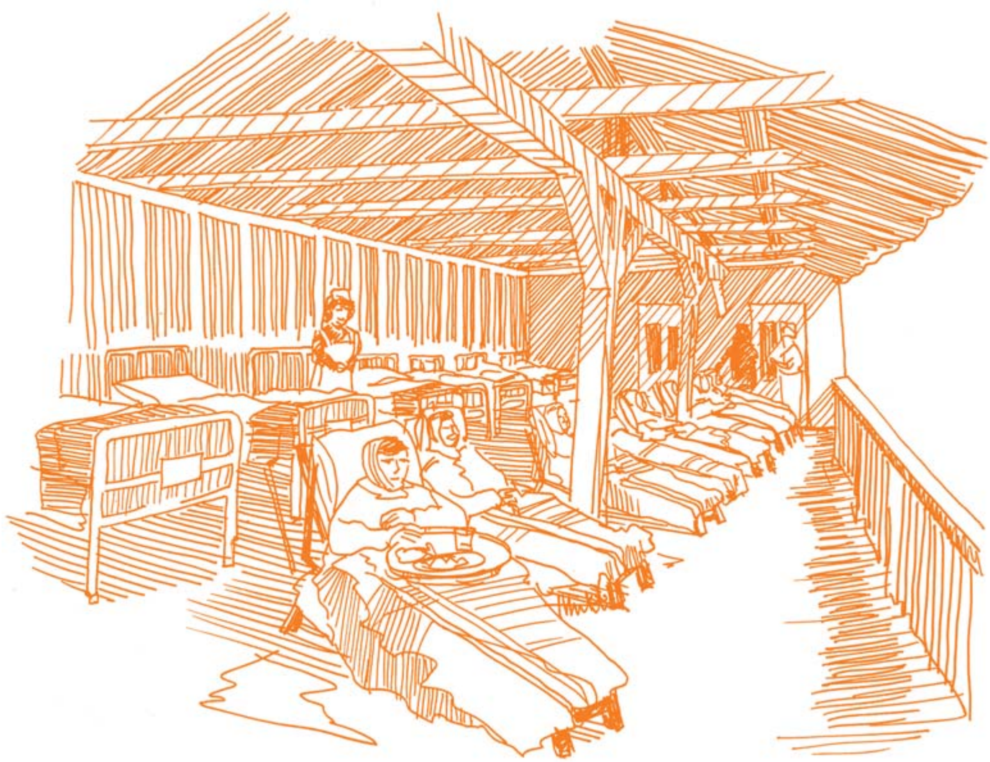
As yet, there does not exist a comprehensive and systematic overview of the evidence for the healing powers of nature and natural elements. Prior systematic reviews of evidence for health benefits of healing environments have been restricted to clinical evidence (Rubin et al., 1998; Ulrich et al., 2004). However, much of the evidence for the health benefits of nature and nature elements has been collected outside clinical settings among healthy populations. Consequently, the narrow focus of previous reviews may have led to an underestimation of the importance of nature and natural elements as components of healing environments.

The aim of the present review is to provide a systematic overview of clinical and other evidence for the health benefits of nature and natural elements as components of healing environments. Four key features were selected that have been the topic of extensive research inside and outside clinical settings: nature, daylight, fresh air and ‘quiet’ (or absence of noise). Chapter 2 first provides a brief historical overview to illustrate the importance of nature and natural elements in the design of hospitals as healing environments. Chapter 3 discusses previous reviews of evidence for the health benefits of healing environments. Chapter 4 provides the details of the current review. Chapter 5 and 6 constitute the core of this review; these chapters discuss the evidence for the health benefits of nature (views of nature, gardens, and indoor plants) and natural elements (daylight, fresh air, quiet). The outcomes and implications of the review are summarized in Chapter 7, along with a discussion of issues that need to be addressed in future research.

2. Healing Environments

The concept of a *healing environment* is rooted in long-standing traditions of complementary medicine and holistic healing. Unlike modern Western medicine, which focuses on the causes of illness (pathogenesis) with curing as the ultimate goal, complementary medicine looks at the causes of health (salutogenesis) with healing as its core mission. Within the latter tradition, a healing environment has been defined as an environment that stimulates healing processes by strengthening an individual's inner powers (Jonas et al., 2003).

Most people have at least some kind of intuitive notion of what a healing environment is (Huelat, 1998). However, there does not yet exist a precise and generally accepted definition of a healing environment. This chapter describes four historical and contemporary examples of hospitals that are generally perceived as healing environments. These examples will show that nature and natural elements have always been key components of healing environments.



Asclepieia of ancient Greece

The Asclepieia of ancient Greece are generally considered to be the first hospitals (or better said, healthcare centers) of Europe (Risse, 1999). Asclepieia were built as temples dedicated to Asclepius, the god of health and healing. Starting in about 300 BC, the cult of Asclepius grew to be very popular. Pilgrims flocked to his healing temples to be healed. At the Asclepieion, they received a wholly spiritual treatment. They slept overnight and reported their dreams to a priest the following day. Because it was widely believed that medical art dealt with changes of a divine nature, healing was considered a gift of the Gods. In fact, the treatment was so spiritual that the patients themselves were not even required to be present at the healing temple. Some ‘patients’ were simply stand-ins for others at home too ill to undertake the pilgrimage (Silverman, 2002).

The architectural design of Asclepieia confirms the spiritual character of the health care provided in these temples (Chatzicocoli-Syrakou, 1997). First, in line with the ancient Greek belief in the divine powers of nature, Asclepieia were mostly erected in valleys at favorable wooded locations near hot or cold springs. While water had important symbolic cleansing values in ancient Greece, it was also favored because people thought that springs possessed oracular or prophetic powers (Risse, 1999). Thus, the presence of nature, particularly the presence of water, was an essential feature of the Asclepieion. Another prominent feature of the Asclepieion was the *abaton*, the dormitory for the patients. Often this feature was a long, narrow building with an open entry facing to the south so that the patients could sleep and dream in a well-ventilated room that was warmed by sunlight.

Monastic infirmaries of the Middle Ages

In the Middle Ages, medical care was closely associated with the religious institutions of the time. Christian charitable organizations such as the order of St. Benedict, which flourished between the 6th and 10th centuries, made it their mission to heal their sick brethren in flesh and spirit. In these days, little was known about physical illness, and ‘healing of the flesh’ was based mostly on notions of classical humorism and folk healing traditions (Risse, 1999). But more important than medical treatment, monastic infirmaries aimed to heal patients in the spirit with rituals of prayer, meditation, rest, and the administration of sacraments. Monks and nuns focused on treating a patient's soul in addition to his or her body because they believed that God had the ultimate authority in people’s health and recovery (Silverman, 2002).

The design of monastic infirmaries contained many elements to promote the spiritual healing process. An important aspect of the layout of the monastery was the garden. Infirmaries in monastic cloisters were deliberately located adjacent to a central courtyard or garden so that patients could contemplate the scenery and make a connection with God. This courtyard was usually designed to symbolize the Garden of Eden referred to in Genesis of the Bible. Patients, in particular sick members of the community, were to lie in small cells with one or two beds that were both placed at the window in order to enable them to benefit from the healing properties of the garden. Gardens were also used to grow medicinal herbs, which were applied in the treatment of patients. In the monastic infirmary, peace and quiet were highly valued, and patients were encouraged to eat their meals in silence.

The pavilion style hospital

The pavilion style hospital was developed in France in the 18th century after a major fire almost destroyed the oldest hospital in Paris, the Hôtel-Dieu (Mens & Tijhuis, 1999). Instead of a single massive structure, the pavilion style hospital consisted of many small, connected buildings or pavilions. It became the standard for hospital design in the mid-19th century in many Western countries (Cook, 2002). Among the enthusiasts for this new style was the nurse Florence Nightingale who witnessed the poor conditions in British military hospitals during the Crimean War (1854-1856) and became an internationally renowned advocate for improved sanitation and care in hospitals. She described many of the healing features of the pavilion style hospital in her book *Notes on Hospitals* (1859).

The pavilion style hospital was explicitly designed to make of use the natural environment as a therapeutic instrument. The natural environment was assumed to exert its positive influence on health through three characteristics: fresh air, sunlight, and peaceful, green surroundings.
In particular the principle of fresh air can be considered quite revolutionary. Until the development of the pavilion style hospital, it had received little attention in the design of healing environments. However, new ideas on the role of 'bad air' and 'vapors' in the transmission of malaria (literally from the Italian, *mal aria*, or bad air) and other diseases led to the recognition of fresh air as one of the most important healing instruments. Unfortunately, because general hospitals needed to be built close to their patients in urban settings, a location among green surroundings was not always feasible. Only more specialized long-term facilities, such as the sanatoriums for tuberculosis patients, could afford to erect their buildings far from the cities in the vicinity of woods and open farmland.

Planetree hospitals

In the late 1970s, more and more people, in particular patients and nurses, became dissatisfied with the sterile and user-unfriendly design and organization of the hospitals of that period (Frampton, Gilpin, & Charmel, 2003). One patient, named Angelica Thieriot, went through such a traumatic hospitals experience that she took the initiative to found Planetree, a nonprofit organization that strives for the transformation of healthcare settings into healing environments. This new approach has been highly successful. Nowadays, more than 70 healthcare facilities have been redesigned and reorganized according to the Planetree model, and numerous other facilities from around the world have adopted similar models of patient-centered care.

The Planetree model provides guidelines for the design and organization of healthcare facilities. With respect to facility design, the model dictates that buildings should include efficient layouts that support the user's needs and create home-like spaces. The design should also foster a connection with nature. Healing gardens, fountains, fish tanks and waterfalls are provided to connect patients, families and staff with the relaxing, invigorating, healing, and meditative aspects of nature. Auditory needs are attended to, understanding that gentle sounds rather than blaring noises may help people to remain calm and regain control.

Conclusion: The importance of nature and natural elements

This select historical overview presents only a few examples of hospitals that can be characterized as healing environments. Nevertheless, even from this brief overview, it becomes clear that a connection with nature has always been a key factor in the design of healing environments. Nature and natural elements, in particular gardens, daylight, fresh air and quiet are recurrent themes that have been applied in the design of hospitals as healing environments throughout the ages. But does it really work? In the following chapters, we will take a closer look at the scientific evidence for the presumed healing powers of nature and natural elements.

3. Evidence-based Design

Traditionally, the design of healing environments has been based on practical experience and philosophical considerations, rather than on scientific evidence. In recent years, however, advocates of healing environments have begun to realize the importance of scientific evidence. Scientific evidence is used to improve the effectiveness of design interventions and to gain the support of healthcare providers, who are trained to rely solely on sound scientific data. This new scientific approach to the design of healing environments is generally referred to as 'evidence-based design'.

This chapter begins with an overview of evidence-based design and how this movement has evolved over the years. Next, the available evidence for the impact of nature and natural elements will be discussed.

An architectural parallel to evidence-based medicine

Evidence-based design has been described as “the architectural parallel and analog to evidence-based medicine” (Hamilton, 2004). Just as practitioners of evidence-based medicine use the best available evidence on the effectiveness of medical interventions to make decisions on the treatment of patients, practitioners of evidence based-design use the best available evidence on the effectiveness of environmental interventions to make decisions on hospital design.

Evidence-based design originally kept a close link to healing environments, focusing on health outcomes as evidence for the effectiveness of these environments (Ulrich, 1992). An important benchmark in the history of evidence-based design was a pioneering study by Roger Ulrich conducted in 1984. This study provided the first rigorous scientific evidence for health impacts of healing environments. Surgery patients with a view of nature suffered fewer complications, used less pain medication, and were discharged sooner than those with a view of a brick wall. In the years since the publication of Ulrich’s study, numerous additional studies by research groups from different countries across the world have reported health benefits associated with views of nature and other design components of medical facilities.

In 1998, Rubin, Owens, and Golden conducted a first systematic review of the rapidly growing literature. The review was carried out under the auspices of the Center for Health Design, a non-profit organization dedicated to improving the quality of healthcare environments. Rubin and her team worked for over 10 years scrutinizing tens of thousands of articles. In the end, they found only 84 studies that linked features of the physical environment to health outcomes, 39 of which were classified as having a “weak study design”. Thus, this first review suggested that there was only limited scientific evidence for the health impacts of healthcare environments. Nevertheless, an encouraging result from this study was that the vast majority (88%) of the studies that met the inclusion criteria found positive correlations between environmental features and health outcomes.

Recently, Ulrich, Zimring, and colleagues (2004) conducted another systematic review for the Center for Health Design. Their review focused on “several areas in which evidence-based design can make a difference”, including staff effectiveness, lower levels of medical errors, prevention of injuries, better acoustics, and positive distraction. Using this broad approach, Ulrich and his team identified more than 600 rigorous studies that point to a link between the physical environment and patient and staff outcomes. According to the authors, this deep and wide evidence base necessitates urgent action to improve the quality of healthcare environments.

The recent review by Ulrich at al. (2004) shows that evidence-based design has extended well beyond its original scope. Nowadays, not only health outcomes, but any type of ‘hard data’ on positive impacts of the healthcare environment are incorporated into the evidence base. Moreover, the kind of environmental features that are taken into consideration are no longer restricted to those that are characteristic of healing environments. Indeed, in their recent review, Ulrich et al. (2004) discuss several design features that seem more typical of the impersonal, sterile buildings that have caused so many traumatic hospital experiences. Among these design features are alcohol-based hand-rub dispensers and ultra-clean ventilation systems that require the sealing of windows.

While evidence-based design has drifted away from healing environments, advocates of healing environments have initiated their own scientific research programs. In particular, the Samueli Institute, a nonprofit medical research organization dedicated to the scientific study of healing processes, has recently launched a major initiative to define the components of healing environments and to set a research agenda to investigate these components (Jonas et al., 2003). The Samueli Institute has coined the term *optimal healing environments* to highlight the scientific character of this approach. The first results of this project have recently been published in a special issue of the Journal of Alternative and Complementary Medicine (Volume 10, October 2004).

Evidence for health benefits of nature and natural elements

As we have seen, there is growing evidence for the impacts of the healthcare environment on patient and staff outcomes, which has been made accessible through systematic reviews. What does this evidence tell us about the health benefits of the four ‘classic’ elements of healing environments: nature, daylight, fresh air, and quiet? Unfortunately, it turns out to be quite difficult to give an accurate estimate of the available evidence for health benefits of these elements on the basis of existing reviews. The most extensive review by Ulrich et al. (2004) was organized in terms of patient and staff outcomes instead of environmental features. This makes it difficult to single out the evidence for health impacts of specific design features. Moreover, this review has employed broad definitions of design features that reach well beyond traditional models of healing environments. For example, as pointed out before, the design feature ‘indoor air quality’ was expanded to include ultra-clean ventilation systems that require the sealing of windows. Research on the health impacts of such systems is undoubtedly relevant and important to the construction of hospitals. However, it is questionable whether such research may qualify as evidence for the benefits of healing environments.

Another limitation of existing reviews is that these have focused almost exclusively on clinical evidence, that is, evidence collected in healthcare settings or among clinical populations. However, the human impacts of nature, daylight, fresh air, and quiet (or noise) are the topics of extensive research fields that extend well beyond the clinical setting. By disregarding the outcomes of this research, reviews within the area of evidence-based design may well have underestimated the available evidence for the health benefits of these elements.

Summary

Evidence-based design has provided scientific justification for deep-rooted notions on the importance of the physical environment for health and healing. In recent years, a substantial knowledge base has become available that can be used by healthcare providers and designers to make optimal decisions on hospital design. This knowledge base contains some evidence for the health impacts of classical elements of healing environments, such as nature, daylight, fresh air and quiet. However, this evidence is difficult to retrieve, and probably incomplete because relevant studies from non-clinical research have not been included. The aim of the present review is to provide a comprehensive overview of evidence for the health benefits of nature, daylight, fresh air, and quiet using outcomes from clinical as well as non-clinical research. The details of this review process are described in the next chapter.

4. The Review

The current review represents a systematic attempt to collate evidence for the health benefits of nature, daylight, fresh air, and quiet in healthcare settings. A systematic review differs from other types of reviews in that it sets out explicit criteria for the scope and types of studies to be included in the review, uses comprehensive search strategies to identify as much as possible from all the relevant research, and specifies explicit rules for assessing the methodological quality and relevance of research (cf. Chalmers & Altman, 1995). This chapter describes how each of these aspects were handled.

Types of studies included in this review

This review includes studies that investigated relationships between physical features of healing environments and health outcomes.

Physical features

The review focuses on the following four physical features:

- Nature (views of nature, visits to gardens, indoor plants);
- Daylight (incl. artificial lamps that mimic daylight);
- Fresh air (supply of outdoor air in buildings);
- Quiet (noise-reducing environmental measures).

The evidence for the health impacts of nature is discussed in Chapter 5. The evidence for the other three elements is discussed in Chapter 6.

An important criterion for the inclusion of studies was whether the way in which the feature was manipulated was relevant to the architecture and design of buildings. Thus, for example, studies on the health impacts of quiet (or noise) were only included if the noise was generated by environmental sources, or modified by design interventions (e.g., noise reducing tiles). In a similar vein, studies on the health impacts of light were only deemed relevant if the light was an integral part of the indoor environment (e.g., windows, lighting systems), not if it was part of a therapeutic intervention.

Health outcomes

There are two types of health outcomes distinguished in this review:

- Clinical outcomes (e.g., length of stay, medicine intake, infection rate, physiological stress measures, mortality);
- Psychological outcomes (e.g., mood states, alertness, quality of sleep, subjective health and well-being).

Only studies that employed quantitative measures of outcomes were included in this review. Thus, studies that employed qualitative measures (e.g., content analysis of personal experiences of patients or staff) were excluded.

Studies of people's environmental preferences and perceptions were judged to lie outside the scope of this review. Similarly, studies that addressed the costs of healthcare (including staff turnover) were judged inappropriate for this review.

Fundamental studies that addressed mechanisms underlying health impacts of environmental features instead of health impacts were not included in the core evidence base. However, some studies that provide important background information are briefly discussed in the relevant sections.

Constraints

Only studies that were published in the English language in peer-reviewed journals after 1975 were taken into consideration.

Search strategy

The literature search was carried out in two steps. First, prior reviews were scrutinized for relevant evidence. These prior reviews varied from simple annotated bibliographies (e.g., Carmona et al., 2001), conceptual reviews (e.g., Devlin & Arneill, 2003; Schweitzer, Gilpin & Frampton, 2004; Ulrich, 1992; Winkel & Holahan, 1985/1986) and systematic reviews based on exhaustive literature scans (Rubin et al., 1998; Ulrich et al., 2004). Specialized reviews of research in various sub-domains including nature (Health Council of The Netherlands, 2004a; Maller et al., 2002; Ulrich, 1999), plants (Pearson-Mims & Lohr, 2000), light (Boyce, Hunter & Bowles, 2003; Veitch, 2001), fresh air (Wargocki et al., 2002; Seppanen & Fisk, 2004) and noise (Health Council of The Netherlands, 2004b) were also examined.

As a second step in the search process, databases such as PubMed and PsychLit and search engines on the Internet were used to search for additional evidence. For all the studies described in this review, at least the abstract was retrieved, and if necessary, the entire article. Annex A provides a brief summary of each of the articles included in the core evidence base.

Assessing the quality and relevance of research

Some studies provide stronger evidence than others. The strength of the evidence depends on the methodological quality of the research and the relevance of the research to the domain of interest, in this case the architecture of healthcare settings.

Methodological quality

The methodological quality of research is determined in large part by the degree of experimental control. To rule out alternative explanations of relationships between environmental variables and health outcomes, a researcher may apply two forms of control:

1. Control over environmental conditions to ensure that health outcomes can be related to the influence of a specific environmental variable;

2. Control over the inclusion of respondents in the study, to ensure that differences in health outcomes between respondent groups cannot be explained by pre-existing personal differences.

There are more and less rigorous forms of control. The most rigorous forms of control are manipulation of environmental variables by the researcher and random assignment of individuals to these manipulated environmental conditions. Unfortunately, in real-life settings such as hospitals, such rigorous control is difficult to implement for reasons related to logistics and limited financial resources.

Throughout this review, a clear distinction has been kept between studies that are well-controlled, such as randomized controlled trials, and studies with weaker designs, such as correlational (or cross-sectional) studies. Studies on multiple design interventions that lack any form of control over environmental or personal variables, such as many post-occupancy evaluation studies, were not included in this review.

Relevance

In general, a study is more relevant to the architecture of healthcare settings if it uses samples from clinical populations (patients, visitors, staff), and/or if it is carried out in a clinical setting. Accordingly, clinical evidence (e.g., evidence from studies conducted in healthcare settings or among clinical populations) has been distinguished from other types of evidence. Non-clinical evidence is not by definition weaker than clinical evidence. However, if a non-clinical study investigated features with a low relevance to healthcare settings (e.g., a visit to a wilderness area, noise from an airport), it was classified as weak evidence, even if the study was well-controlled.

Table 1 provides an overview of the different types of evidence distinguished in this review. Studies of types a and b are classified as 'strong evidence'. Studies of types c and d are classified as 'weak evidence'.

Table 1: Overview of types of evidence included in this review

	Clinical Evidence	Other Evidence
Strong design	a	b
Weak design or weak relevance to healthcare settings	c	d

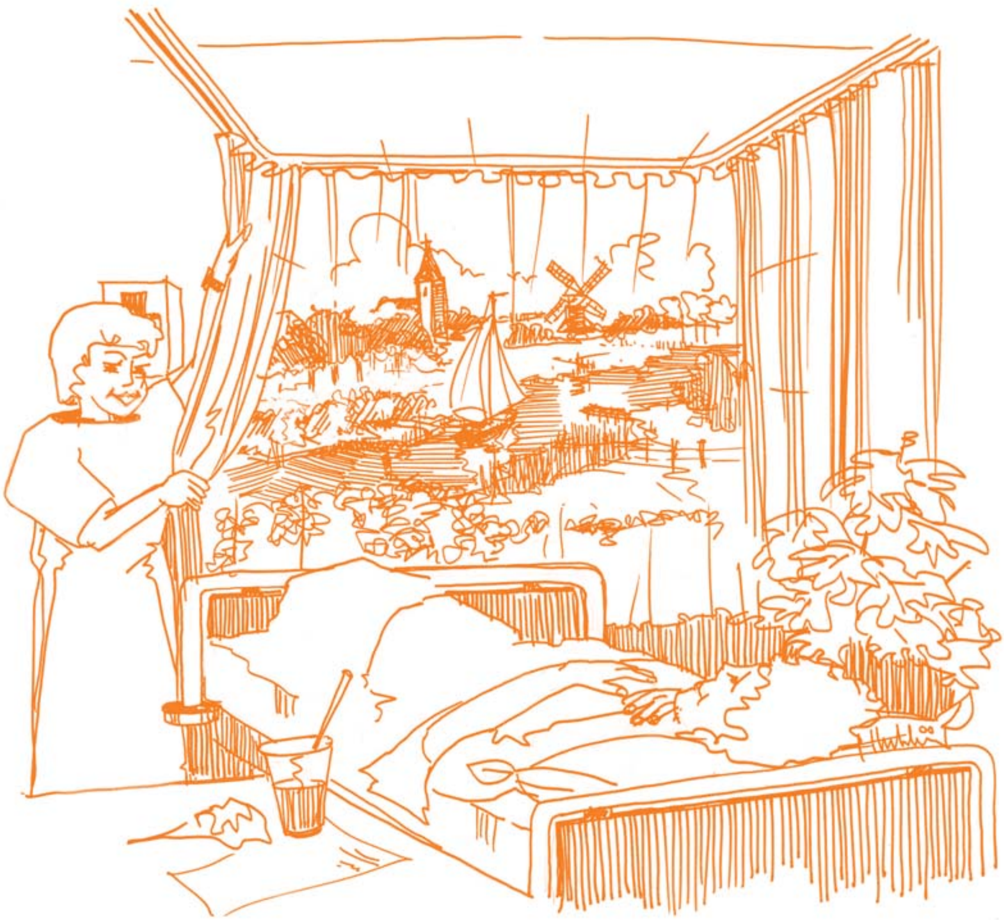
Summary

This chapter has set out the details of the review process. Basically, it was decided to:

- Include studies that:
  - Investigated impacts of nature, daylight, fresh air, and quiet;
  - Employed clinical and/or psychological health outcomes.
- Exclude studies that:
  - Were not published in peer-reviewed journals;
  - Were not published in the English language;
  - Were published before 1975;
  - Employed qualitative measures;
  - Measured people's environmental preferences and perceptions;
  - Addressed costs of healthcare (including staff turnover);
  - Addressed outcomes only indirectly related to health and well-being;
  - Lacked any form of control over environmental or personal variables;
  - Are not relevant to the architecture and design of buildings.
- Make use of the outcomes of previous reviews in the search process;
- Make a distinction between;
- Clinical and non-clinical evidence:
  - Strong and weak evidence.

5. Health Benefits of Nature

There are various ways in which patients, visitors, and hospitals staff can come into contact with nature. They can view nature from a window or on wall-mounted pictures, they can visit a natural setting such as a garden or nearby park, or they may come into contact with indoor plants or flowers. This chapter describes the scientific evidence for health benefits of these different types of interactions between people and the natural environment.



Views of nature

A great number of studies have shown that people, in general, experience views of nature as beautiful and beneficial to their health (see Ulrich, 1993, for a review). In particular, this research has found that viewing nature is an effective means of providing relief from stress and pain. Several researchers have proposed that these so-called *restorative effects* of nature are the result of an ancient evolutionary history (Ulrich, 1993; Kaplan, 1995). According to these authors, evolution has made nature an innate source of fascination and restoration in order to stimulate people to seek contact with non-threatening natural environments that contain resources and opportunities that are necessary for survival.

Clinical evidence

The health benefits of real or simulated views of nature in clinical settings have been investigated in at least ten studies[1]. One of these studies is the well-known dossier study by Ulrich (1984) among patients who underwent gall bladder surgery. A remarkable finding of this study was that patients who were assigned to a room with a view of nature after their surgery required fewer strong painkillers compared to those who were assigned to a room with a view of a brick wall. This suggests that views of nature may act as a natural painkiller. However, other explanations cannot be ruled out. In particular, a weakness of this study is that pairs of patients were matched within a rather broad range of six years. In that period, numerous changes could have taken place in the hospital that may have caused differences in medication needs between pairs of patients.

Six experiments on the benefits of so-called "distraction therapy" provide additional support for the pain-reducing effects of views of nature (Miller, Hickman, & Lemasters, 1992; Tse et al., 2002a, 2002b; Diette et al., 2003; Schneider et al., 2003, 2004). In general, these studies have shown that patients report less pain and display a higher pain tolerance when they are exposed to nature scenes (with or without sounds) while undergoing painful procedures. For example, in a recent study by Diette et al. (2003) 80 patients who were undergoing a painful bronchoscopy procedure were randomly assigned to either a neutral condition or a condition in which nature scene murals were placed at the bedside. Results show that patients in the natural intervention condition reported less pain than patients in the control condition, after adjustment for age, gender, race, education, health status, and dose of narcotic medication. These results are consistent with the notion that views of nature may provide relief from pain. However because of the lack of equally distracting,

[1] Another, well-designed and frequently cited study by Ulrich, Lundén & Eltinge (1993) on the effects of exposure to nature paintings on patients recovering from heart surgery does not fulfill the inclusion criteria of this review because it has not been published in a peer-reviewed journal.

non-natural control conditions, such as murals of urban settings, results of these studies do not provide evidence for the superior pain-relieving quality of views of nature as compared to other interventions.

A well-controlled study by Ulrich, Simons & Miles (2003) among 876 blood donors employed a stronger design with appropriate control conditions. This study showed that blood donors in a waiting room had lower blood pressure and pulse on days when a wall mounted television displayed a videotape of natural settings (a park and a stream), compared to days when the television displayed a videotape of urban settings (a commercial street and shopping mall). Blood donors also had lower blood pressure and pulse on days when the television was off, as compared to days when the television displayed continuous daytime programs. The restorative effects of watching videotapes of nature were equally strong as the restorative effects of watching no television. Thus, although this study confirms the superior restorative quality of views of nature as compared to views of urban settings, it does not support the notion that views of nature are better than viewing nothing at all.

Finally, two studies have investigated the beneficial effects of viewing aquariums on institutionalized elderly. In a study by DeSchriver and Riddick (1990), 27 elderly, aged 62 and older, first received a cognitive stressor and were then randomly placed in front of an aquarium, a video of an aquarium, or a static television screen for eight minutes. Results did not reveal any significant differences in physiological stress reduction between the treatment groups, everyone perceived whatever treatment they had as relaxing. However, it should be noted that this study had only limited power to detect differences between the treatments due to the small number of respondents. Another study by Edwards and Beck (2002) investigated the influence of viewing an aquarium on food intake of 62 individuals with Alzheimer's disease. The results of this well-controlled study show that Alzheimer's patients who viewed an aquarium while eating showed higher increases in food intake than patients in a control group who viewed a scenic ocean picture. Observational data suggested that these effects may be explained by the fact that patients with a history of pacing and wandering sat for longer periods at the dinner table. Moreover, patients who tended to be lethargic were more attentive and awake in the presence of the aquariums, which may also have increased their nutritional intake.

Other evidence

At least 13 non-clinical studies attest to the health benefits of viewing nature, most of which are also described in a recent review by the Health Council of The Netherlands (2004a). Nine of these studies consist of well-controlled experiments with strong designs (Ulrich, 1979; Ulrich et al., 1991;

Hartig et al., 1996, Study 1[2]; Parsons et al., 1998; Fredrickson & Levenson, 1998; Lauman et al., 2003; Van den Berg, Koole & Van der Wulp, 2003; Fredrickson & Branigan, in press, Study 1 & Study 2).

In a typical experiment, healthy volunteers first receive a stress-induction treatment (watching a scary movie, or performing fatiguing tasks). Next, they are randomly assigned to conditions of viewing videos or slides of natural versus built environments. Stress is assessed before and after the stress-induction, and after viewing the natural or built environments. Results of such experiments have consistently shown that stressed individuals who are exposed to scenes dominated by natural content show more positive mood changes, perform better on concentration tasks, and display more pronounced changes characteristic of physiological stress recovery than stressed individuals who are exposed to scenes dominated by built content. These restorative effects have been found for all kinds of natural environments, including forests, rural scenery, waves on the beach, and golf courses. Thus far, only one study (Parsons et al., 1998) has compared the effectiveness of various types of natural scenes on stress recovery. Results indicated that taking a simulated drive through a golf course was more relaxing than taking a simulated drive through forest scenery.

In addition to these experimental studies, at least four quasi-experimental studies[3] with weaker designs have compared groups of respondents who stayed for prolonged periods in spaces that offered window views on natural or built environments (Tennessen & Cimprich, 1995; Kuo, 2001[4]; Fayber-Taylor, Kuo & Sullivan, 2003; Kaplan, 2001). Although respondents in these studies were not randomly assigned to conditions of natural or built window views, there was usually some degree of control for systematic differences among groups. Results of these field studies suggest that adults and children (in particular females) who live in houses with views of urban nature have a greater ability to concentrate and are less aggressive and more self-disciplined than individuals who live in houses with views of built environments. They also report greater well-being (Kaplan, 2001).

[2] This article also contains a second study, which does not meet the inclusion criteria of this review due to lack of proper control conditions.

[3] A frequently cited study by Moore (1982) among prisoners is not included in this review because views of nature were confounded with privacy.

[4] See also Kuo & Sullivan (2001) for more data on this same group of respondents.

Discussion

More than 20 studies have demonstrated a relationship between views of nature and health outcomes, in particular stress reduction. Thus, there is substantial evidence that viewing nature is beneficial to people's health. Nevertheless, for optimal application in healthcare settings, more data on the effectiveness of different views of nature in different clinical populations is needed. For example, it is conceivable that certain types of nature scenes, such as strong waves or dark rainforests, are less suitable for certain groups of patients (e.g., psychotic patients, Alzheimer patients). In a similar vein, it is conceivable that views of unspectacular nature, such as trees and grass, are less effective for long-term patients who are bed-ridden and deprived of stimulation. These patients may benefit more from viewing more spectacular nature scenes or more lively (real or simulated) urban settings.

Gardens

An increasing number of healthcare facilities have started to create "healing gardens" near or even inside their buildings to accommodate the needs of patients, family members, and staff. In doing so, they make use of insights into the therapeutic benefits of gardens as they have been described by landscape architects and other experts (e.g., Cooper Marcus & Barnes, 1995; Gerlach-Spriggs, Kaufman & Warner, 1998; Sadler, 2001; Ulrich, 2002). According to these experts, a visit to nature not only provides beautiful and restorative views, it may also improve people's health and well-being through other mechanisms, such as exercise and fostering access to social support. But as we will see, the wide-spread belief in the benefits of healing gardens has thus far received little back-up from rigorous scientific research.

Clinical evidence

The literature search did not reveal any studies on the beneficial effects of the use of gardens near healthcare settings that met the criteria for inclusion in this review[5]. One study by Cimprich & Ronis (2003) investigated the effects of home-based nature activities among a clinical population. In this intervention study, 157 women with newly diagnosed breast cancer were randomly assigned to a nature-based intervention or a nonintervention group. The intervention comprised a home-based program involving 120 minutes of nature-based activities (e.g., visiting a scenic spot, tending plants or gardens, sitting by a window with natural views) per week for a period of about five weeks. Attention capacity was measured at the start of the intervention (before surgery) and at the end of the intervention (after surgery). The intervention group showed significantly greater improvement in

[5] A carefully designed study by Whitehouse et al. (2001) does not meet the criteria for inclusion in this study because it lacked proper control conditions (e.g., pre-test measures of mood, etc.)

performance on attention tasks from the start to the end of the treatment period than the nonintervention group. The groups were controlled for differences in education, extent of surgery and other variables. A weakness of this study is that the women in the nonintervention group did not receive an alternative treatment that was unrelated to nature. Therefore, alternative interpretations of the effects in terms of a greater sense of participation in self-care cannot be ruled out. Moreover, the intervention comprised a wide range of activities, which makes it impossible to distinguish effects of visits to gardens and other types of nature from effects of views of nature.

Other evidence

Outside the clinical setting, at least four studies have investigated the health benefits of visiting nature. In one well-controlled study (Hartig, Mang & Evans, 1991, Study 2), 34 healthy students who were fatigued from performing mentally fatiguing tasks were randomly assigned to one of three conditions: walking through an urban park, walking through a built-up area near the park, and passive relaxation inside a building without window views. Results showed that students who walked through the park displayed more positive changes in mood, and performed better on a post-test concentration task. These findings were replicated in a quasi-experimental study among backpackers who went on a wilderness trip (Hartig et al, 1991, Study 1) and in a more recent experimental study among students who walked through a wilderness area (Hartig et al, 2003). In this recent experiment, Hartig and colleagues also found evidence that walking through nature provided positive changes in physiological stress. However, because these latter two studies focused on remote wilderness areas instead of urban nature, the results are less relevant for application to hospital settings.

A five-year cohort study among 3144 inhabitants of Tokyo aged 70 years or older found a significant relationship between the presence of ‘walkable green spaces’ in urban neighborhoods and longevity. The probability of five-year survival of the senior citizens increased significantly in proportion to the space for taking a stroll and the number of parks and treelined streets near the residence. The relationship between walkable green space and longevity was statistically controlled for confounding variables such as age, gender, socio-economic status and income. Nevertheless, alternative explanations in terms of self-selection of the respondents (e.g., elderly in the green neighborhoods were stronger and healthier to begin with, and thus had greater a-priori life-expectancy) cannot be ruled out.

Discussion

Despite the widespread belief in the therapeutic effects of gardens near healthcare settings, such effects have not yet been demonstrated in a rigorous, controlled manner. Positive outcomes of a few studies in the context of urban nature and wilderness provide grounds for assuming that being in nature is indeed beneficial to people's health and well-being. An important challenge for future research is to replicate these findings for gardens near healthcare settings. Once such evidence has become available, research can begin to address more detailed questions on the effectiveness of different types of gardens for different (clinical) populations and different health outcomes.

Indoor plants

People associate plants with personal well-being and perceive them as soothing and healing. Giving plants or flowers to a friend or relative who is ill has become customary in many parts of Western society. These intuitive notions and practices are supported by growing evidence that indoor plants and flowers can indeed improve people's health. Most importantly, plants may reduce stress levels and mental fatigue, lift people's mood, and absorb harmful substances in the air[6]. The evidence for these beneficial effects of indoor plants will be reviewed below.

Clinical evidence

In hospitals, plants and flowers are traditionally viewed as reservoirs for pathogenic bacteria that may cause disease. Accordingly, most research on plants and flowers in clinical settings has focused on health risks rather than health benefits (see LaCharity et al., 2003, for an overview). As yet, this research has failed to demonstrate an association between bacterial organisms present in the soil of plants and the water of flowers and hospital infections (e.g., Bartzokas, Holley, & Sharp, 1975; Siegman-Igra et al., 1986). Nevertheless, investigators recommend prudence and caution in the application of potted plants and flowers in hospitals, especially in acute care settings with susceptible patients.

A study by Fjeld (2000, Study 2) investigated potential health benefits of plants in a clinical setting. Foliage plants and full-spectrum lamps were placed in the radiology department of a Norwegian hospital. On average, the 48 employees in this department reported a 25% decrease in typical 'sick building' symptoms, such as fatigue, feeling heavy headed, headache, dry throat and dry or itchy hands. The design of this study suffers from several weaknesses. Because the effects of plants and full-spectrum lamps were confounded, it is not possible to conclude whether these health benefits were caused by the plants or the lamps. Moreover, since this study lacked control groups

[6] Because the presence of harmful substances in the air is directly related to health, it was considered appropriate to include this type of evidence in this review. However, evidence of more indirect health effects of plants, such as increasing humidity levels, filtering dust from the air, or dampening sounds (e.g., Lohr & Pearson-Mims, 1996) were judged to lie outside the scope of this review.

that did not receive any treatment or different treatments, alternative explanations in terms of a change in routine or special attention from researchers are also possible.

Other evidence

Fjeld (2000, Study 3) investigated the health benefits of foliage plants and full-spectrum light among 120 pupils in a junior high school. This study, which suffered from the same confounding between plants and lights as the study among hospital workers (Fjeld 2000, Study 2), showed that pupils in experimental classrooms displayed 21% less symptoms of discomfort. In another study among 51 office workers, Fjeld and colleagues (Fjeld et al., 1998; see also Fjeld, 2000, Study 1) manipulated the presence of plants without varying the amount of light. They also employed proper control conditions with nature posters on walls. Results of this well-controlled study once again showed a 23% decrease in symptoms of discomfort among workers in offices with plants.

One possible explanation for the health benefits of plants as demonstrated by Fjeld and colleagues (1998) is an increase in (perceived) air quality. In line with this explanation, at least eight laboratory studies have shown that plants can absorb harmful substances from the indoor air (Giese et al, 1994; Oyabu et al., 2001, 2004 (Study 1 & 2); Wolverton, McDonald & Watkins, 1984; Wolverton, McDonald & Mesick, 1985; Wolverton & Wolverton, 1993; Wolverton & Wolverton, 1996). For example, a group of German scientists (Giese et al., 1994) labeled formaldehyde with a radioactive carbon 14 tag and followed its absorption and metabolic destruction inside a spider plant (Chlorophytum comosum). The radioactive carbon 14 tag showed that the formaldehyde was metabolized and converted into food products such as organic acids, sugars and amino acids. Notably, the plants in this study became more effective at converting toxic chemicals into food the longer they were exposed to the chemicals. Similar effects have been found for other potentially harmful substances such as carbon dioxide and benzene.

A limitation of most research on air purification by plants is that it has been conducted under artificial circumstances in sealed test chambers or energy-efficient buildings. A recent study by Oyabu et al. (2004, Study 2) provides additional evidence for the effectiveness of potted plants to purify the air in real-world room spaces. Three pots with plants were installed in an office room where formaldehyde was emitted continuously. The concentration was decreased up to 60% by installing the pots[7]. These findings suggest that results of highly artificial experiments on air purification by plants have some validity in the real world. However, it remains a weakness of this

[7] A recent, not yet published, investigation by Burchett and colleagues in Australia (Burchett et al., 2004) found similar effects of pot plants in office rooms on organic gases (TVOCs).

type of research that absorption of harmful substances by plants has not yet been related to actual health outcomes.

Plants may also affect health through psychological mechanisms, such as mood improvement or reduction of stress and pain. At least six studies have investigated such psychological impacts of plants in offices. A frequently cited study by Lohr et al. (1996) showed that participants who were randomly assigned to perform a complex task in a computer room with plants showed quicker responses and less stress than participants who performed the same task in a room without plants. These findings were replicated by Russell (1999), who found that participants who performed a complex task in a heavily planted room showed less stress as indicated by lower skin conductance than participants who performed the same task in a room with no plants. A weakness of both of these studies was that they lacked control conditions with equally distracting, non-natural stimuli. A well-controlled study by Lohr & Pearsons-Mims (2000) provides more convincing evidence for the pain-reducing effects of plants. They found that more subjects were willing to keep a hand submerged in ice water for five minutes if they were in a room with plants present than if they were in a room without plants, or in a room with equally distracting colorful objects.

Other well-controlled studies on psychological influences of plants in offices have reported more mixed results. For example, Adachi, Rohde, & Kendle (2000) found that the presence of a floral display in a room where participants were watching a movie increased positive feelings of composition and confidence, but also negative feelings of annoyance. Similarly, the presence of a foliage display increased feelings of clear-headedness, but also bad temper. Larsen et al. (1998) investigated the impact of the density of plants in a workplace on concentration and mood. They found that mood increased with increasing density of plants, but concentration decreased with increasing density of plants. Shibata & Suzuki (2002) found a positive effect of the presence of highly visible plants on performance of a creativity task in men but not in women.

Discussion

Plants undoubtedly have been, and continue to be, important decorative elements in healthcare settings, particularly in waiting rooms and other public areas. Fear that plants and flowers may transmit disease through their soil and water has not been confirmed by research. In contrast, research is beginning to document the benefits of indoor plants for human comfort, air quality, and well-being. However, this research area clearly needs more study, especially since several studies have documented negative psychological impacts (e.g., lower concentration levels). Apparently, more work is needed to identify the circumstances under which the presence of plants may contribute positively and/or negatively to health and well-being.

Summary

Table 2 provides a summary of the 45 studies discussed in this chapter. Only one third of these studies employed a strong design, and only 12 studies were carried out in a clinical setting or among clinical populations. Nearly all studies showed positive outcomes on at least one dependent variable. Two studies found negative psychological impacts for contact with indoor plants.

The amount and strength of the evidence differs considerably depending on which type of interaction with nature is studied. First, there is substantial and convincing evidence that viewing nature on a screen or through a window can promote relief from stress and pain. Second, there is only limited and weak evidence that an actual visit to a natural setting such as a garden or park is beneficial to people's health. Third, there is extensive but mostly weak evidence for the health benefits of contact with indoor plants and flowers. Thus, counter-intuitively, the health benefits of direct contact with 'real' nature are less well established than the benefits of viewing nature on a screen or through a window.

An important limitation of research on the health benefits of nature is that the majority of studies have employed psychological outcome measures, in particular stress-related measures. Since chronic stress is known to be a causative factor of cardiovascular and gastrointestinal disease, the stress-reducing effects of nature certainly merit a large amount of attention in research. However, it would improve the credibility of this research if more studies could demonstrate that contact with nature can indeed help to fight disease and illness.

In sum, while there is mounting evidence for the stress-reducing effects of viewing nature, the clinical implications of these effects are less well-established. Furthermore, there is a lack of rigorous clinical evidence on the health benefits of contact with 'real nature', such as gardens or plants. Fear that plants and flowers may transmit disease in hospitals has not been confirmed by research. However, the finding that some studies have reported negative psychological impacts for indoor plants warrants prudence and caution in the application of 'real nature' inside hospitals.

Table 2: Summary of evidence for health benefits of nature

NATURE	Clinical		Non-clinical		Total	Positive	Negative
	Strong	Weak	Strong	Weak	number	impacts	impacts
Views of nature	2	8	9	4	23	21	-
Gardens	-	1	1	3	5	5	-
Indoor Plants	-	1	5	11	17	17	2
Totals	*2*	*10*	*15*	*18*	*45*	*43 (96%)*	*2 (4%)*

The evidence

Views of nature

1. DeSchriver, M.M. & Riddick, C.C. (1990). Effects of watching aquariums on elders' stress. *Anthrozoos, 4*, 44-48.
2. Diette, G.B., Lechtzin, N., Haponik, E., Devrotes, A., & Rubin, H.R. (2003). Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: A complementary approach to routine analgesia. *Chest, 123* (3), 941-948.
3. Edwards, N. & Beck, A. (2002). Animal-assisted therapy and nutrition in Alzheimer's Disease. *Western Journal of Nursing Research, 24*, 697-712.
4. Faber Taylor, A., Kuo, F.E., & Sullivan, W.C. (2002). Views of nature and self-discipline: evidence from inner city children. *Journal of Environmental Psychology, 22*, 49-63.
5. Fredrickson, B.L., & Branigan, C. (in press, Study 1 & 2). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition and Emotion*.
6. Fredrickson, B.L. & Levenson, R.W. (1998). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. *Cognition and Emotion, 12*, 191-220.
7. Hartig, T., Böök, A., Garvill, J., Olsson, T., & Gärling, T. (1996, Study 1). Environmental influences on psychological restoration. *Scandinavian Journal of Psychology, 37*, 378-393.
8. Kuo, F.E. (2001). Coping with poverty: Impacts of environment and attention in the inner city. *Environment & Behavior, 33* (1), 5-34.
9. Kaplan, R. (2001). The nature of the view from home: Psychological benefits. *Environment and Behavior, 33*, 507-542.
10. Laumann, K., Gärling, T., & Stormark, K.M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology, 23*, 125-134.
11. Miller, A.C., Hickman, L.C., & Lemasters, G.K. (1992). A distraction technique for control of burn pain. *Journal of Burn Care and Rehabilitation, 13* (5), 576-580.
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14. Schneider, S.M., Prince-Paul, M., Allen, M.J., Silverman, P., & Talaba, D. (2004). Virtual reality as a distraction intervention for women receiving chemotherapy. *Oncology Nursing Forum*, *31* (1), 81-88.
15. Tennessen, T.M. & Cimprich, B. (1995). Views to nature: effects on attention. *Journal of Environmental Psychology, 15*, 77-85.

16. Tse, M.M.Y., Ng, J.K.F., Chung, J.W.Y., & Wong, T.K.S. (2002a). The effect of visual stimuli on pain threshold and tolerance. *Journal of Clinical Nursing, 11* (4), 462-469.
17. Tse, M.M.Y., Ng, J.K.F., Chung, J.W.Y., & Wong, T.K.S. (2002b). The effect of visual stimulation via the eyeglass display and the perception of pain. *Cyberpsychology & Behavior*, *5* (1), 65-75.
18. Ulrich, R. (1979). Visual landscapes and psychological well-being. *Landscape research, 4*, 17-23.
19. Ulrich, R.S. (1984). View through a window may influence recovery from surgery. *Science, 224*, 420-421.
20. Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*, 201-230.
21. Ulrich, R.S., Simons, R.F., & Miles, M.A. (2003). Effects of environmental simulations and television on blood donor stress. *Journal of Architectural & Planning Research, 20* (1), 38-47.
22. Van den Berg, A.E., Koole, S.L., & Van der Wulp, N.Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology, 23*, 135-146.

Gardens

1. Cimprich, B. & Ronis, D. (2003). An environmental intervention to restore attention in women newly diagnosed with breast cancer. *Cancer Nursing 26* (4), 284-292.
2. Hartig, T., Evans, G.W., Jamner, L.D., Davis, D.S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23*, 109-123.
3. Hartig, T., Mang, M., & Evans, G.W. (1991, Study 1 and Study 2). Restorative effects of natural environment experience. *Environment and Behavior, 23*, 3-26.
4. Takano, T., Nakamura, K., & Watanabe, M. (2003). Urban residential environments and senior citizens' longevity in megacity areas. The importance of walkable green spaces. *Journal of Epidemiological Community Health, 56*, 913-918.

Plants

1. Adachi, M., Rohde, C.L.E., & Kendle, A.D. (2000). Effects of floral and foliage displays on human emotions. *HortTechnology, 10*, 59-63.
2. Fjeld, T. (2000, Study 2 & Study 3) The effect of interior planting on health and discomfort among workers and school children. *HortTechnology, 10*, 46-52.
3. Fjeld, T., Veiersted, B., Sandvik, L., Riise, G., & Levy, F. (1998). The effect of indoor foliage plants on health and discomfort symptoms among office workers. *Indoor and Built Environments, 7*, 204-209.

4. Giese, M., Bauer-Doranth, U., Langebartels, C., & Sandermann, H. (1994) Detoxification of formaldehyde by the spider plant (*Chlorophytum comosum L.*) and by soybean (*Glycine max L.*) cell suspension cultures. *Plant Physiology, 104* :1301-1309.
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10. Russel, H. (1999). The psychological effects of plants on people in offices. *Interiorscape*, 19-21.
11. Shibata, S. & Suzuki, N. (2002). Effects of the foliage plant on task performance and mood. *Journal of Environmental Psychology, 22*, 265-272.
12. Wolverton, B. C., McDonald, R. C., & Watkins, Jr., E. A. (1984) Foliage plants for removing indoor air pollutants from energy-efficient homes. *Economic Botany* 224-228
13. Wolverton, B.C., McDonald, R.C., & Mesick, H.H. (1985). Foliage plants for the indoor removal of the primary combustion gases carbon monoxide and nitrogen oxides. *Journal of the Mississippi Academy of Sciences, 30*, 1-8.
14. Wolverton, B.C. & Wolverton, J.D. (1993). Plants and soil microorganisms: Removal of formaldehyde, xylene and ammonia from the indoor environment. *Journal of the Mississippi Academy of Sciences, 38*, 11-15.
15. Wolverton, B.C., Wolverton, J.D. (1996). Interior plants: Their influence on airborne microbes inside energy-efficient buildings. *Journal of the Mississippi Academy of Sciences, 41*, 99-105.

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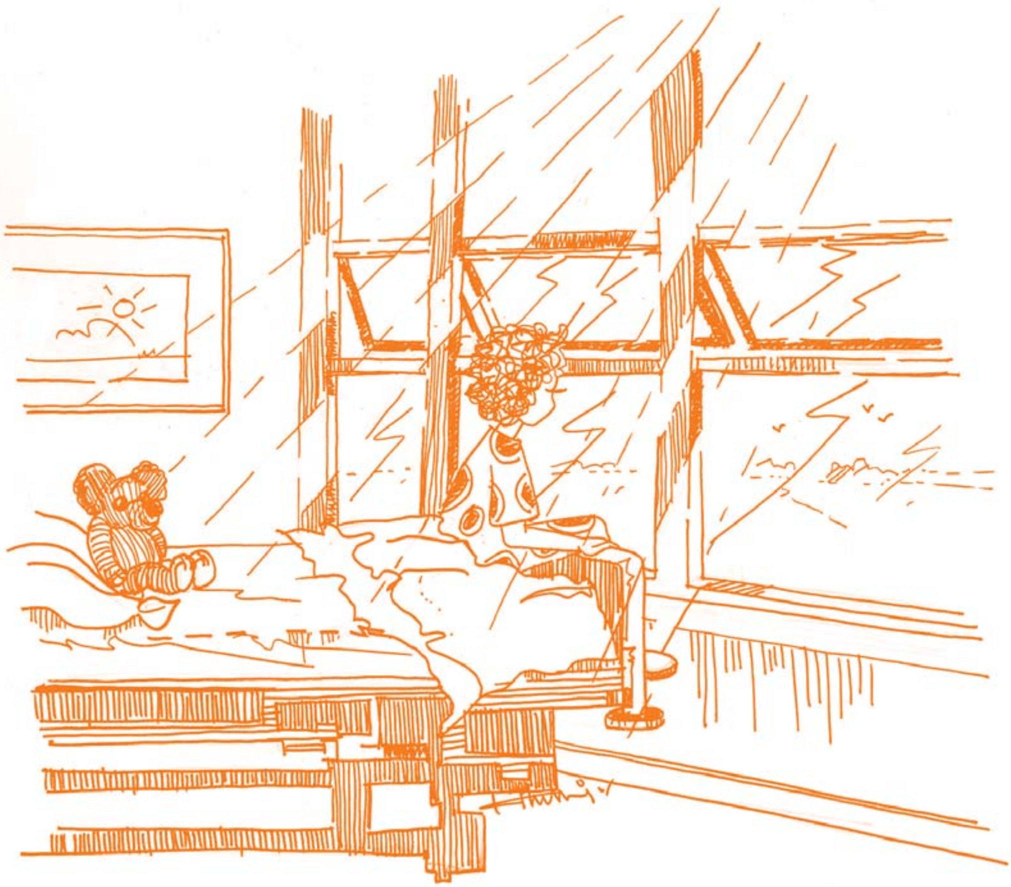

6. Health Benefits of Natural Elements

The ambient environment, in terms of daylight, fresh air, and sound, has been the subject of a significant amount of research. This chapter describes the evidence that is relevant to the design of healthcare settings as healing environments.

Daylight

There is no doubt that people prefer daylight to electric lighting as their primary source of illumination. Studies in the USA (Heerwagen & Heerwagen, 1986), Canada (Veitch, Hine, & Gifford, 1993) and the UK (Cuttle, 2002) have consistently shown that the majority of survey respondents prefer to work and live in buildings illuminated by daylight. People do not only prefer daylight because it is more pleasant than electric light, they also tend to believe that daylight is beneficial for one's health. For example, in a survey by Heerwagen and Heerwagen (1986), 73% of the respondents indicated that they thought that daylight is better for general and visual health than electric lighting.

Daylight tends to be brighter and it has a more balanced spectrum of colors than most artificial light sources. Theoretically, there are three routes by which these properties of daylight may positively influence health and well-being (Boyce et al., 2003): through the visual system (e.g., increased visibility), the biological system (e.g., improvement of thr circadian cycle), or the psychological system (e.g., alleviation of depression). This section reviews the empirical evidence for health benefits of daylight and artificial lights that mimic properties of daylight.

Clinical evidence

Exposure to artificial high-intensity light (bright light therapy) has been successfully used in the treatment of patients with seasonal affective disorder and Alzheimer's disease (e.g., Ancoli-Israel et al, 2003; Terman & Terman, 1999). Based on these findings, a number of researchers have proposed that exposure to natural daylight may also be linked to favorable health outcomes. Up to now, these ideas have been tested in five studies, all with serious flaws and weaknesses.

Three retrospective dossier studies have investigated the link between sunny hospital rooms and length of stay and mortality. A study among 174 patients with severe depression found that patients in sunny rooms had a 2.6-day shorter stay than patients in dull rooms (Beauchemin and

Hays, 1996). In this study, all the sunny rooms had an outdoor view, while all the dull rooms had a courtyard view. Therefore, it is possible that the difference in length of stay was caused by a difference in the quality of the view, rather than the amount of sunlight. A study among 415 unipolar and 187 bipolar depressed inpatients found that bipolar patients in rooms with direct sunlight in the morning had a 3.67-day shorter stay on average than patients in rooms with sunlight in the evening (Benedetti et al., 2001). A third study among 628 patients in an intensive care unit who had had a first heart attack revealed that female patients who were treated in sunny rooms had a 1.1-day shorter stay on average than female patients in dull rooms (Beauchemin and Hays, 1998). Moreover, mortality in both sexes was consistently higher in dull rooms (12%) than in sunny rooms (7%). The latter two studies provide no information on the type of view from the windows, which makes it impossible to conclude whether sunlight was manipulated independently from the content of the view.

A prospective randomized study among 20 patients with seasonal affective disorder showed that patients who were treated for one week with a daily one-hour morning walk outdoors (natural light) showed reduced depressive symptomatology and improved patterns of melatonin and cortisol secretion as compared to patients in a control group who were treated with low-dose artificial light (Wirz-Justice et al., 1996). Since it is clear that a morning walk involves factors other than just light exposure (e.g., increased motor behavior and decreased temperature), these findings do not provide unequivocal evidence for the beneficial effects of daylight per se, as compared to other factors.

Finally, a recent prospective study of pain medication use among 89 patients undergoing spinal surgery showed that patients staying on the bright side of the hospital (with an average 46% higher-intensity sunlight) experienced less perceived stress, marginally less pain, and took 22% less analgesic medication per hour than patients on the dim side of the hospital (Walch et al., 2005). Although this study was much better controlled than previous studies on health benefits of sunlight, it is still likely that amount of sunlight was confounded with type of view. On the dim side of the hospital, the sunlight was blocked by an adjacent building located 25 meters away. Thus, patients on the dim side of the hospital probably had a less natural view than patients on the bright side of the hospital.

Other evidence

Outside the clinical setting, there exists a long tradition of research on human impacts of indoor lighting. This research has been dominated by investigations of relationships between luminance and visual task performance, with the result that it is now well understood how light levels affect visibility (see Veitch, 2001, for a review). Since visual task performance is not a health outcome, this research lies outside the scope of this review. In recent years, an increasing number of studies have investigated health effects of indoor lighting, in particular effects on mood, and alertness/ sleepiness. Only one of these studies investigated the benefits of daylight (Wilkins et al., 1989, correlational study). In this study, it was found that employees in offices that overlooked a six storey light well suffered more headaches the lower the office was within the well and thus the less the amount of daylight. These findings cannot be explained by differences in the content of view, since all floors looked out on the offices on the opposite side of the light well. However, employees were not randomly assigned to floors, so alternative explanations in terms of differences in organization culture or composition of staff across floors cannot be ruled out.

At least six studies[8] have investigated health benefits of so-called 'full-spectrum' lamps that mimic daylight (Baron et al., 1992, Study 1; Boray et al., 1989; Knez, 2001; Küller & Wetterberg, 1993; Veitch, Gifford, & Hine, 1991; Veitch, 1997). None of these studies provide support for the positive effects of full-spectrum fluorescent lighting on mood or health. A frequently cited study by Baron et al. (1992, Study 1) failed to demonstrate hypothesized positive effects of full-spectrum light on mood. Another study by Boray et al. (1989) among 117 students found no differences in self-reported arousal between warm white, cool white, and full-spectrum lighting at approximately equal levels of illuminances. A study by Knez (2001) among 108 students also found no differences in mood changes between conditions of warm, cool, and full-spectrum lighting. Küller and Wetterberg (1993) studied the effects of full-spectrum and 'warm' light at high and low illuminance levels in a laboratory made to look like an office environment. They did not find evidence for an alerting effect of full-spectrum light as measured by delta activity in EEG patterns. By contrast, they did find that a condition involving full-spectrum lamps with a high illuminance evoked a decrease in social evaluations of the office space, and an increase in visual discomfort.

Veitch and colleagues (1991; Veitch, 1997) tested the hypothesis that positive beliefs about full-spectrum lighting, rather than the lamp itself, underlie the persistent anecdotal reports of the benefits of full-spectrum light. Their research failed to find consistent support for this hypothesis. However, results of both studies confirmed that type of lamp (cool white fluorescent vs. full-spectrum) in itself did not influence self-reported mood or task performance.

A number of studies have systematically varied levels of illuminance and lamp color. These studies have reported somewhat inconsistent results. For example, Küller and Wetterberg (1993) found

[8] A study by Wohlfarth & Gates (1985) on the effects of full spectrum light in schools on blood pressure and mood was discarded because of poor control conditions and poor reporting of results.

that participants' EEGs showed less delta activity at higher lighting levels (1700 lux) than at low lighting levels (450 lux), indicating that bright light has an alerting effect on the central nervous system. However, Baron et al. (1992) found that *lower* illuminances were generally associated with positive affect and task performance, while Knez (1995) reported no significant changes in mood or task performance after exposure to bright or dim light. Similarly inconsistent findings have been reported for lamp color.

Knez and colleagues (Knez, 1995, Study 1 and Study 2; Knez & Engmarker, 1998; Knez & Kers, 2000, Knez, 2001) have argued that the inconsistent findings from research on lamp color and illuminance may be partly explained by the fact that age and gender differences have not been taken into account. Consistent with this explanation, they found that impacts of lamp color on mood and performance differed between men and women, and older and younger people. However, different effects of gender were found in different studies. For example, Knez (1995, Study 1) found that exposure to cool light increased negative affect in women, but not in men, while Knez and Engmarker (1998) found that exposure to warm light increased negative affect in women, but not in men. Accordingly, it seems that the role of personal characteristics in effects of lamp color and illuminance is not yet completely understood and needs more research.

Finally, two experimental studies have shown that flicker from fluorescent light can cause stress and headaches, even when it is not visible (Wilkins et al., 1989, experimental study; Küller & Laike, 1998). These findings attest to the benefits of daylight, since it is certainly free of flicker. However, flicker can also be prevented by using high-frequency circuit controls instead of conventional controls.

Discussion

In modern buildings, daylight is mostly integrated as an architectural statement and for energy savings. The results of this brief review suggest that the benefits of daylight may extend beyond architecture and energy. Consistent with classical ideas about healing environments, exposure to daylight in healthcare settings has been associated with positive health outcomes such as reduced length of stay, medication intake, and depression. However, because most studies have confounded daylight with the content of the view from the window, more research on this issue is needed. The notion that artificial lights that mimic the properties of daylight is beneficial for people's health has thus far not received support from empirical studies. However, there is some indication that certain properties of indoor lighting, such as luminance level, lamp color, and flicker can affect people's mood and performance, even though the precise conditions under which positive or negative effects occur are not well understood.

Taken together, it can be concluded that the research on the health benefits of daylight and indoor lighting conditions that mimic daylight is as yet far from conclusive and suffers from serious weaknesses. There is more disagreement than agreement about many dimensions within the scientific literature, and a considerable research effort will be necessary in order to identify the best luminous conditions for health outcomes.

Fresh air

The process in which 'stale' indoor air is exchanged for 'fresh' outdoor air is generally referred to as ventilation. The rate at which the indoor air is renewed per unit of time is called the 'ventilation rate', which is usually measured in liters per second (l/s). Ventilation can be achieved by natural or mechanical systems, the main difference being that mechanical ventilation systems use (electric) fans to drive the air. Air-conditioning systems are advanced mechanical ventilation systems that modify the temperature and humidity of the fresh air before it is released into the indoor environment. These systems often have a low ventilation rate because they recycle air from the indoor environment.

Ventilation may improve people's health in several ways: by providing air for breathing, by removing and diluting indoor pollutants, by adding or removing moisture, and by heating or cooling the indoor environment. Ventilation may also have harmful effects on indoor air quality and climate if contaminated air is sucked in (Seppänen & Fisk, 2004). This section reviews the scientific evidence for the health benefits and health risks of ventilation in clinical and other settings.

Clinical evidence

Research on health impacts of ventilation in clinical settings has focused primarily on the health risks of ventilation systems and the benefits of installing High Efficiency Particulate Air (HEPA) filters in those systems. At least three well-controlled studies have shown that ventilation in hospitals can cause an outbreak of infections during construction activities, when the outdoor air that is brought in is filled with dust and other harmful particulates (Loo et al., 1996; Opal et al., 1986; Oren et al., 2001). In each of these studies, the outbreak could be controlled by the installation of HEPA-filter air purifiers and other measures that purify or block the outdoor air, such as sealing windows.

Two studies have investigated the health benefits of increased ventilation in clinical settings. In a well-controlled study by Everett & Kipp (1991), ventilation rates by air-conditioning systems in three operating rooms were systematically varied to assess the impact on infection rates. Results showed that increasing the supply of outdoor air in summer led to a decrease in infection rate among 1998 patients. A retrospective study among 690 elderly residents of a nursing home found that attack rates of influenza were much higher in buildings with 30% or 70% recirculation of indoor air, than in buildings with no recirculation of air (Drinka et al., 1996). These findings speak to the benefits of fresh air in buildings. However, participants were not randomly assigned to the buildings, and the ventilation system type was confounded with other architectural factors, such as the amount of public space and office space. Therefore, it is possible that the lower influenza rates in one of the buildings were caused by factors other than the ventilation systems.

Non-clinical evidence

The non-clinical literature on the health effects of ventilation in non-industrial indoor environments (offices, schools, homes, etc.) has recently been reviewed by a multidisciplinary group of European scientists, called EUROVEN (Wargocki et al., 2002). The group found 30 studies[9] that provided conclusive data on the health effects of ventilation, 22 of which meet the inclusion criteria of this review. An additional search revealed two additional, more recently published studies (Myatt et al., 2002; Wargocki, Wyon & Fanger, 2004).

Nine well-controlled studies investigated the relationship between ventilation rates in schools and offices and self-reported Sick Building Syndrome (SBS) symptoms. Six studies found that higher ventilation rates were generally associated with decreases in self-reported SBS symptoms (Apte et al, 2000; Jaakkola et al., 1991, experimental study; Jaakkola & Miettinen, 1995a; Smedje et al., 2000; Sundell et al., 1994; Wargocki et al., 2000). A recent experimental study by Wargocki et al. (2004) showed that the positive effects of increased outdoor air supply were only obtained with new filters. When the new filters were replaced with old filters, SBS symptoms increased again, despite the higher ventilation rate. In two studies, no effects were found on self-reported SBS symptoms for an altered ventilation rate (Jaakkola et al, 1991, cross-sectional analysis; Menzies et al., 1993).

Six studies investigated the relationship between ventilation rates in homes, schools, a jail and an army training camp and medically diagnosed health outcomes. In five well-controlled studies, it was found that higher ventilation rates were related to a decrease in health outcomes such as asthma and pneumonia (Brundage et al., 1988; Hoge et al., 1994; Norbäck et al, 1995; Øie et al, 1999; Wäliner et al., 1998). One study (Warner et al., 2000) found that the installation of mechanical ventilation systems (which presumably increased ventilation) in homes of 40 asthmatic patients improved their histamine levels. However, ventilation rates were not measured, so alternative

[9] The EUROVEN group also detected 43 studies with serious weaknesses and flaws, most of which detected positive relationships between ventilation rate and health. These studies are not discussed in the present review, although some of these studies might qualify as weak evidence.

explanations for these findings in terms of other characteristics of the ventilation system are also viable.

Two well-controlled studies investigated the relationship between ventilation rates in offices and sick leave. In one study, it was found that lower levels of outdoor air supply led to an increase in sick-leave among 3,720 hourly employees of a large manufacturer in 40 buildings with 115 independently ventilated work areas (Milton et al., 2000). Another study among 294 hourly workers reported no effects on sick leave for an altered ventilation rate (Myatt et al., 2002).

Seven well-controlled studies investigated relationships between ventilation system types and self-reported SBS symptoms. Six studies found that self-reported SBS symptoms were higher in air-conditioned buildings than in naturally or mechanically ventilated buildings (Burge et al, 1987; Fisk et al., 1993; Jaakkola & Miettinen, 1995b; Mendell et al., 1996; Skov et al., 1990; Zweers et al., 1992). One study found no increased risk of SBS symptoms in buildings in which air was recirculated by the ventilation system (Sundell et al., 1994).

Discussion

This review of the health impacts of fresh air underlines the importance of taking into account both clinical and non-clinical evidence when assessing impacts of the physical environment on health. Until now, clinical research has focused almost exclusively on health risks of ventilation. This research has shown that under certain circumstances, such as construction activities, the supply of outdoor air may cause an outbreak of infections, especially among susceptible patients. Based on these findings, it has been recommended to add ultra-clean HEPA filters to ventilation systems which require the sealing of patient windows (Schulster & Chinn, 2003). However, one may wonder whether the benefits of such drastic measures outweigh the negative side effects of depriving patients and staff of fresh air.

There is now strong evidence from research in non-clinical settings, such as homes, schools, and offices, that the supply of fresh air via ventilation is associated with positive health outcomes, such as decreased SBS symptoms, decreased asthma, and decreased sick leave. Furthermore, the non-clinical literature indicates that in buildings with air-conditioning systems there may be an increased risk of SBS symptoms compared with naturally or mechanically ventilated buildings, and that improper maintenance, design, and functioning of air-conditioning systems contributes to increased prevalence of SBS symptoms. Taken together, these findings strongly suggest that, under normal circumstances, natural and mechanical ventilation systems that allow generous amounts of fresh air into healthcare buildings are preferable to air-conditioned systems. Only in unusual circumstances (e.g., during construction activities), or in spaces that require the highest standards of air quality (e.g., operating theaters and Intensive Care Units), are ultra-clean air-conditioned systems preferable to natural ventilation.

Quiet

There is little doubt that hospital environments are less than peaceful. Excessive noise in hospitals may be generated by three types of sources: (1) personnel and other people; (2) equipment; and (3) environmental design and acoustics (Milette & Carnevale, 2003). This section focuses on the evidence for the influence of the latter source of noise on health outcomes.

Clinical evidence

There is substantial evidence that noise can have negative effects on patients and staff (see Biley, 1994; Millette & Carnevale, 2003; Schuster & Weber, 2003; Stansfeld et al, 2000; Topf, 2000, for reviews). In particular, noise has been found to increase the need for oxygen in neonates, disturb sleep patterns in children and adults, and increase stress levels. Unfortunately, the role of environmental design in these negative effects of noise is less well-established. A few studies have demonstrated a relationship between noise-reducing environmental interventions such as the application of sound-absorbing tiles on noise levels (e.g., Berens & Weigle, 1996; Philbin & Gray, 2002; Schuster & Weber, 2003[10]). However, most of these studies did not measure actual health impacts of noise-reducing measures.

Only two studies have measured actual health impacts of noise-reducing environmental interventions in clinical settings. A well-controlled study by Berg (2001) showed that EEG-arousals in 12 sleeping subjects were significantly reduced when reverberation time was reduced with sound-absorbing ceiling-tiles. Hagerman et al. (2005) changed the acoustics in a coronary heart unit by replacing the ceiling tiles with sound-absorbing tiles. They compared the cardiovascular condition of 31 patients who were in the unit before the change (during “bad acoustics”) to the condition of 63 patients who were in the unit after the change (during “good acoustics”). Patients with acute myocardial infarction and unstable angina showed lower pulse amplitude during the night in the good acoustics period. Moreover, the overall incidence of rehospitalization was higher for the bad acoustics group. A weakness of this study is that the “good” and “bad” acoustics groups consisted of different individuals and were not randomly assigned. However, the outcomes were controlled for differences in age, gender, and severity of illness.

[10] A frequently cited study by Moore et al. (1998) is not mentioned here because the “environmental intervention” (closing patient room doors) was behavioral rather than environmental.

Other evidence

The relationship between noise and health is the topic of an extensive field of research, with its own professional associations and journals. A great deal of this research has focused on the health impacts of exposure to traffic noise (e.g., noise from airplanes, trains, cars) in schools, houses and offices. In a recent review of this literature, the Health Council of The Netherlands (2004b) identified more than 100 empirical studies that demonstrated the adverse effects of traffic noise, at least 50 of which were published in peer-reviewed journals. The main conclusion of this review is that there is sufficient evidence that traffic noise can negatively affect sleep quality (measured by physiological and self-reported measures) and well-being (measured by the use of sleeping pills and self-reported mood). These findings have some relevance for the architecture of hospitals, since hospitals are often located in urban settings near roads, railways and other sources of traffic noise. However, compared to indoor noise, traffic noise is a relatively unimportant source of noise in hospitals. Moreover, architects and designers usually have only limited freedom in the selection of building sites, which is subject to numerous constraints. Therefore, studies on the negative health impacts of exposure to traffic will not be included in the body of evidence for health impacts of hospital environments.

Ohrstrom and Björkman (1983) investigated traffic noise related sleep disturbance in an apartment building before and after the installation of noise insulating windows. A weakness of this study is that only three tenants were investigated. However, each of these three tenants that participated in this study demonstrated a decrease in the number of body movements after the windows had been insulated, and two reported improved sleep quality. Two other studies by Fidell & Silvati (1991) and Utley et al. (1986) used much larger samples to investigate the effectiveness of residential insulation to reduce annoyance by traffic noise. However, none of these studies measured actual health outcomes.

Discussion

There is substantial and consistent evidence from clinical and non-clinical studies that noise exposure can harm people's health and well-being. This evidence attests to the importance of quiet in healthcare settings. However, the role of the physical environment in the health impacts of noise (or quiet) is less well-established. Research on the adverse effects of traffic noise in non-clinical populations provides some indirect evidence for the beneficial effects of locating healthcare settings in quiet and peaceful surroundings. However, it has not yet been established that exposure to traffic noise constitutes a health risk for people in healthcare settings. Studies on the effectiveness of noise-reducing environmental interventions to reduce decibel levels provide some indirect evidence for the importance of design measures to reduce the negative health impacts of noise. However, as yet, direct evidence for a relationship between noise-reducing environmental measures and health is very scarce. Taken together, the interrelations between the physical environment, noise, and health are clearly an area of great importance and future research potential.

Summary

Table 3 provides a summary of the 52 studies on the health impacts of daylight, fresh air, and quiet that were discussed in this chapter. Most of these studies (82%) employed a strong design, but less than one-quarter of the studies were carried out in clinical settings or among clinical populations. The outcomes do not attest unequivocally to the benefits of natural elements. Just over 60% of the studies showed positive outcomes on at least one dependent variable. Seven studies found negative impacts on health for daylight and fresh air.

The amount and strength of the evidence varies considerably across the three elements. For daylight and fresh air it is now well-established that these elements can positively influence health, although more research in clinical settings and among clinical populations is needed. In particular, the finding that quite a few studies have demonstrated negative health impacts for daylight and fresh air warrants the need for more clinical research. The evidence for the health benefits of quiet is more indirect. On the one hand, there is ample evidence for negative health impacts of noise (and thus, health benefits of quiet) from clinical and non-clinical research. On the other hand, the role of the physical environment in producing or reducing negative health impacts of noise has only been demonstrated in a handful of studies.

In sum, while there exists a wealth of evidence for health benefits of daylight, fresh air, and quiet, more research is needed to identify the optimal environmental conditions for the application of these benefits in clinical settings. This is particularly true for daylight and fresh air, which have also been associated with health risks.

Table 3: Summary of evidence for health benefits of natural elements

AMBIENT	Clinical		Non-clinical		Total	Positive	Negative
CONDITIONS	Strong	Weak	Strong	Weak	number	impacts	impacts
Daylight	-	5	14	1	20	8	4
Fresh air	4	1	23	1	29	22	3
Quiet	1	1	-	1	3	3	-
Totals	*5*	*7*	*37*	*3*	*52*	*33 (63%)*	*7 (14%)*

The evidence

Daylight

1. Baron, R.A., Rea, M.S., & Daniels, S.G. (1992, Study 1,2,3). Effects of indoor lighting (illuminance and spectral distribution) on the performance of cognitive tasks and interpersonal behaviors: The potential mediating role of positive affect. *Motivation and Emotion, 16*, 1-33.
2. Beauchemin, K.M., & Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders, 40* (1), 49-51.
3. Beauchemin, K.M., & Hays, P. (1998). Dying in the dark: Sunshine, gender and outcomes in myocardial infarction. *Journal of the Royal Society of Medicine, 91* (7), 352-354.
4. Benedetti, F., Colombo, C., Barbini, B., Campori, E., & Smeraldi, E. (2001). Morning sunlight reduces length of hospitalization in bipolar depression. *Journal of Affective Disorders, 62* (3), 221-223.
5. Boray, P.F., Gifford, R., & Rosenblood, L. (1989). Effects of 'warm' white, 'cool' white, and full-spectrum fluorescent lighting on simple cognitive performance, mood and ratings of others. *Journal of Environmental Psychology, 9*, 297-308.
6. Knez, I. (1995, Study 1 & Study 2). Effects of indoor lighting on mood and cognition. *Journal of Environmental Psychology, 15*, 39-51.
7. Knez, I. (2001). Effects of colour of light on nonvisual psychological processes. *Journal of Environmental Psychology, 21*, 201-208.
8. Knez, I. & Engmarker, I. (1998). Effects of office lighting on mood and cognitive performance and a gender effect in work-related judgment. *Environment and Behavior, 4*, 580-594.
9. Knez, I., & Kers, C. (2000). Effects of indoor lighting, gender, and age on mood and cognitive performance. *Environment and Behavior, 6*, 817-831.
10. Küller, T., & Laike, R. (1998). The impact of flicker from fluorescent lighting on well-being, performance and physiological arousal. *Ergonomics, 41*, 433-447.
11. Küller, R, Wetterberg, L. (1993). Melatonin, cortisol, EEG, ECG and subjective comfort in healthy humans: Impact of two fluorescent lamp types at two light intensities. *Lighting Research and Technology, 25* (2), 71-81
12. Veitch, J.A. (1997). Revisiting the performance and mood effects of information about lighting and fluorescent lamp type. *Journal of Environmental Psychology, 17*, 253-262.
13. Veitch, J.A., Gifford, R., & Hine, D.W. (1991). Demand characteristics and full spectrum lighting effects on performance and mood. *Journal of Environmental Psychology, 11*, 87-95.
14. Walch, J.M., Rabin, B.S., Day, R., Williams, J.N., Choi, K., & Kang, J.D. (2005). The effect of sunlight on post-operative analgesic medication usage: A prospective study of spinal surgery patients. *Psychosomatic Medicine, 67* (1), 156-163.

15. Wilkins, A.J., Nimmo-Smith, I., Sater, A.J., & Bedocs, L., (1989, Study 1 & 2). Fluorescent lighting, headaches and eyestrain. *Lighting Research and Technology, 21*, 11-18.
16. Wirz-Justice, A., Graw, P., Krauchi, K., Sarrafzadeh, A., English, J., Arendt, J., & Sand, L. (1996). 'Natural' light treatment of seasonal affective disorder. *Journal of Affective Disorders, 37* (2-3), 109-20.

Fresh air

1. Apte, M.G., Fisk, W.J. and Daisey, J.M. (2000). Associations between indoor CO2 concentrations and sick building syndrome symptoms in US office buildings: an analysis of the 1994-1996 BASE study data, *Indoor Air, 10*, 246-257.
2. Brundage, J.F., Scott, R.M., Lednar, W.M., Smith, D.W. & Miller, R.N. (1988). Building-associated risk of febrile acute respiratory diseases in Army trainees. *Journal of the American Medical Association, 259*, 2108- 2112.
3. Burge, S., Hedge, A., Wilson, E., Bass, J.H. & Robertson, A. (1987). Sick Building syndrome: a study of 4,373 office workers. *Annals of Occupational Hygiene, 31*, 493-504
4. Drinka, P.J., Krause, P., Schilling, M., Miller, B.A., Shult, P. & Gravenstein, S. (1996). Report of an outbreak: nursing home architecture and influenza-A attack rates, *J. Am. Geriatr. Soc., 44*, 910- 913.

5. Everett W.D., & Kipp, H. (1991). Epidemiologic observations of operating room infections resulting from variations in ventilation and temperature. *American Journal of Infection Control, 19* (6), 277-82.
6. Fisk, W.J., Mendell, M.J., Daisey, J.M., Faulkner, D., Hodgson, A.T., Nematollahi, M., & Macher, J.M. (1993). Phase 1 of the California healthy building study. *Indoor Air, 4*, 246-254
7. Hoge, C.W., Reichler, M.R., Dominguez, E.A., Bremer, J.C., Mastro, T.D., Hendricks, K.A., Musher, D.M., Elliott, J.A., Facklam, R.R. & Breiman, R.F. (1994). An epidemic of pneumococcal disease in an overcrowded, inadequately ventilated jail. *New England Journal of Medicine, 331*, 643-648
8. Jaakkola, J.J., & Miettinen, P. (1995a). Ventilation rate in office buildings and sick building syndrome. *Occupational and Environmental Medicine, 52*, 709-714.
9. Jaakkola, J.J. & Miettinen, P. (1995b). Type of ventilation system in office buildings and sick building syndrome, *American Journal of Epidemiology, 141*, 755-765.
10. Jaakkola, J.J.K., Heinoneon, O.P, & Seppanen, O. (1991). Mechanical Ventilation in Office Buildings and the Sick Building Syndrome. An Experimental and Epidemiological Study. *Indoor Air, 1*, 111-121
11. Loo, V.G., Bertrand, C., Dixon, C., Vitye, D., DeSalis, B., McLean, A.P., et al. (1996). Control of construction-associated nosocomial aspergillosis in an antiquated hematology unit. *Infection Control and Hospital Epidemiology, 17* (6), 360-364.

12. Mendell, M.J., Fisk, W.J., Deddens, J.A., Seavey, W.G., Smith, A.H., Smith, D.F., Hodgson, A.T., Daisey, J.M., & Goldman, L.R. (1996). Elevated symptom prevalence associated with ventilation type in office buildings. *Epidemiology, 7*, 583- 589.
13. Menzies, R., Tamblyn, R.M., Farant, J-P, Hanley, J., Nunes, F., Tamblyn R.T. (1993). The effect of varying levels of outdoor-air supply on the symptoms of sick building syndrome. *New England Journal of Medicine, 328*, 821-827
14. Milton, D., Glencross, P., & Walters, M. (2000). Risk of sick-leave associated with outdoor air supply rate, humidification and occupants complaints. *Indoor Air, 10*, 212-221.
15. Myatt, T.A., Staudenmayer, J., Adams, K., Walters, M., Rudnick, S.N., & Milton, D.K. (2002). A study of indoor carbon dioxide levels and sick leave among office workers. *Environmental Health,1* (1):3.
16. Norbäck, D., Björnsson, E., Janson, C., Widström M.J., & Boman, G. (1995). Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings. *Occupational and Environmental Medicine, 52*, 388-395.
17. Øie, L., Nafstad, P., Botten, G., Magnus, P., & Jaakkola, J.K. (1999). Ventilation in homes and bronchial obstruction in young children. *Epidemiology, 10*, 294- 299.
18. Opal, S.M., Asp, A.A., Cannady, P.B., Jr., Morse, P.L., Burton, L.J., & Hammer, P.G. (1986). Efficacy of infection control measures during a nosocomial outbreak of disseminated aspergillosis associated with hospital construction. *Journal of Infectious Diseases, 153* (3), 634-637.

19. Oren, I., Haddad, N., Finkelstein, R., & Rowe, J.M. (2001). Invasive pulmonary aspergillosis in neutropenic patients during hospital construction: Before and after chemoprophylaxis and institution of HEPA filters. *American Journal of Hematology, 66* (4), 257-262.
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23. Wälinder, R., Norbäck, D., Wieslander, G., Smedje, G., Erwall, C. & Venge, P. (1998). Nasal patency and biomarkers in nasal lavage - the significance of air exchange rate and type of ventilation in schools. *International Archives of Occupational and Environmental Health, 71*, 479-486.
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25. Wargocki, P., Wyon, D.P., Sundell, J.,Clausen, G., & Fanger, P.O. (2000).The effects of outdoor air supply rate in an office on perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity. *Indoor Air, 10*, 222-236.
26. Warner, J.A., Frederick, J.M., Bryant, T.N., Wiech, C., Raw, G.J., Hunter, C., Stephen, F.R., McIntyre, D.A. & Warner, J.O. (2000). Mechanical ventilation and high-efficiency vacuum cleaning: a combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma. *Journal of Allergy and Clinical Immunolology, Part 1, 105*, 75-82.
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Quiet

1. Berg, S. (2001). Impact of reduced reverberation time on sound-induced arousals during sleep. *Sleep, 24* (3), 289-292.
2. Ohrstrom, E. & Bjorkman, M. (1983). Sleep disturbance before and after traffic noise attenuation in an apartment building. *Journal of the Acoustical Society of America, 73* (3), 877-9.
3. Hagerman, I., Rasmanis, G., Blomkvist, V., Ulrich, R., Anne Eriksen, C., & Theorell, T. (2005). Influence of intensive coronary care acoustics on the quality of care and physiological state of patients. *International Journal of Cardiology, 98* (2), 267-70.

7. General Discussion

The preceding two chapters have reviewed 97 studies, representing thirty years of research on the health impacts of nature, daylight, fresh air, and quiet. The fact that more than 60% of these studies were published in the last ten years reflects the growing interest in the scientific underpinnings of the health benefits of healing environments.

This chapter begins with a summary of the main conclusions. Next, needs for future research will be discussed, followed by a summary of design guidelines and recommendations for further reviews.

Conclusions

How strong is the evidence?

Nature, daylight, fresh air, and quiet are often mentioned together as a ‘classical recipe’ for creating healing environments. However, the present literature review indicates that the empirical evidence for the effectiveness of this recipe varies considerably depending on which ingredient is being considered. This makes it impossible to draw any general conclusions on the strength of the evidence for these four elements.

For each element separately, the available evidence can be summarized as follows:

- There is solid evidence that ventilation of fresh air is associated with improved self-reported and medically diagnosed health;
- There is sufficient evidence that viewing nature can reduce stress and pain;
- There is weak evidence that the presence of indoor plants can lift people's mood and reduce self-reported symptoms of physical discomfort;
- There is weak and inconclusive evidence for health benefits of daylight in buildings;
- There is some evidence for health benefits of environmental measures that promote quiet in buildings;
- There is a lack of direct evidence for benefits of visits to ‘healing gardens’.

Health risks

Not all the studies included in this review found positive outcomes. In particular, for fresh air, daylight, and indoor plants, there were some indications that the presence of these features can also have negative impacts on psychological and/or clinical health outcomes. In most of the studies which revealed negative outcomes, qualifying conditions which had probably influenced the results could be identified. For example, negative health impacts of fresh air were only found when the outdoor air was contaminated by construction activities. Whether bright lights and lamp colors produce a deterioration in mood seemed to depend on what the individual's preferences and expectations are. And for plants and flowers, it appears that abundance and excessive colorfulness can induce annoyance and complaints. In sum, it can be concluded that the health risks of nature, daylight, fresh air and quiet in healthcare settings are small, and can be controlled by taking the right precautions.

The added value of non-clinical evidence

An important aim of the present review was to open up the non-clinical literature on the health benefits of nature, daylight, fresh air and quiet for application to the domain of healthcare settings. The inclusion of this literature has significant added value. On average, about 75% of the evidence included in this review comes from studies among healthy populations in non-clinical settings. Thus, if healthcare decision makers were to rely on the clinical literature alone, they would presumably underestimate the health benefits of nature and natural elements in healthcare settings. In some cases, exclusive reliance on clinical evidence may even lead to biased conclusions and unfounded decisions. In particular for indoor plants and fresh air, clinical research has traditionally focused on health risks rather than health benefits. By ignoring the non-clinical literature on health benefits of these elements, healthcare decision makers run the risk of making decisions that fail to meet the needs of large groups of patients, visitors, and staff.

Healthy versus healing environments

The present review focused only on elements of healthcare environments that are generally perceived as healing. Even with the inclusion of non-clinical evidence, the conclusions are less optimistic than those of previous reviews that were not restricted to healing environments, such as the review by Ulrich et al. (2004). This finding underlines the importance of distinguishing between healing and healthy environments in evidence-based design. Features that are generally perceived as healing, such as gardens and sunlight, are not necessarily most effective when it comes to improving health. Conversely, features that have a large impact on people's health, such as sinks and handcleaner dispensers, are not necessarily experienced as healing and soothing for the soul.

Assuming that the creation of buildings that are both healthy and healing is the ultimate goal of healthcare design, evidence for the health benefits of features that are perceived as healing as well as evidence for health risks of features that are perceived as not healing should be given the highest priority in healthcare design. Evidence for health benefits of elements that are perceived as unattractive and not healing is less readily applicable, as is evidence on health risks of elements that are perceived as attractive and healing. This ambiguous evidence requires a careful balancing of physical health benefits against the psychological well-being of patients and staff.

Taken together, it can be concluded that the architecture of hospitals has much to gain from considering the combined impacts of environmental features on health and healing.

Research needs

A number of actions can be undertaken to improve the quality of the research base on health benefits of healing environments. In general, there should be more coordination of efforts across clinical and non-clinical research disciplines. Furthermore, studies should be designed that meet the standards of medical research and that allow for accumulation of results by examining common outcome variables.

More specifically, the following recommendations for further research on health benefits of healing environments can be made:

1. *Design research with adequate control conditions*. Controlled research requires a basis for comparison such that alternative explanations for observed results can be eliminated. Typically, medical research accomplishes this through the formation of randomly formed groups, one of which receives a treatment/intervention and one that does not. However, because environmental interventions are often confounded with other variables, additional control groups that receive different interventions are typically required to rule out effects of these confounding factors. Furthermore, in order to establish a good comparative base, pre-measures need to be collected and analyzed so that groups can be matched or, alternatively, statistical control can be applied.
2. *Target health outcomes as the primary outcome variable*. Although it is useful and interesting to know about users' preferences and perceptions of environmental interventions, it is more important to obtain data on people's health as an outcome variable. Preferably, research studies should include multiple measures of health that combine both psychological and clinical measures.
3. *Conduct more epidemiological studies*. In healthcare research, epidemiological (or correlational) studies have traditionally been used mostly for prevention purposes, to identify the demographic, behavioral, and biological risk factors for certain diseases. However, the research on ventilation discussed in this review shows that this type of research is also very useful for identifying the environmental correlates of health and well-being. The inclusion of large numbers of (healthcare) settings and subjects allows for statistical control of possible confounding variables, and at the same time ensures a high external validity. In designing 'environmental epidemiological' studies, evidence-based design has much to learn from experiences with this type of research in toxicology and other fields that study environmental risks (Weed, 2002).

Design guidelines

The present review focused on (quasi-)experimental studies that were designed to establish causal relationships between design features and health outcomes. The applied value of this type of research lies mainly in the fact that it provides a rationale for redesigning hospitals. However, because the findings cannot readily be generalized to complex, real-life settings, experimental research is not the best source for detailed guidelines on how to implement certain design measures. Despite these inherent limitations, the studies in this review provide enough information to formulate some general design guidelines. These guidelines are:

1. *Install ventilation systems that allow a generous supply of fresh air*. Under normal circumstances, natural and mechanical ventilation systems that allow fresh air into healthcare buildings should be preferred over air-conditioned systems. Only in unusual circumstances, e.g., during construction activities, in very hot climates, or in spaces that require the highest standards of air quality, are air-conditioned systems preferable to natural ventilation. Mechanical ventilation systems should always be implemented with a maintenance program that ensures efficient operation.
2. *Provide visual access to nature*. Offer patients, visitors and staff the opportunity to enjoy views of gardens, trees and other natural elements inside and outside the building. Ensure that reception desks, beds, seats and other furniture are placed in such a way that users have access to views of nature. Put up video screens or wall-mounted pictures displaying nature scenes in areas where people are under stress or have to undergo painful procedures. Avoid obstacles, such as parking lots, that obstruct views of nature from windows or doors.
3. *Use sound-absorbing ceiling tiles*. There is no doubt that excessive noise is bad for people's health. Sound-absorbing ceiling tiles are an effective means to create a quiet environment that improves health.
4. *Be cautious with the application of daylight and lamps that mimic daylight in buildings*. Although daylight is generally preferred, it is not always beneficial to people's health. The effectiveness of daylight will depend on how it is delivered. Therefore, design measures aimed at improving lighting conditions should be carefully evaluated and tested prior to implementation.
5. *There is no need to avoid indoor plants in hospitals*. Plants and flowers are often avoided in hospitals out of fear that they can spread disease. At present, there is no empirical evidence to support this notion. As a precaution, plants and flowers should be avoided in units with susceptible patients. However, in all other areas, plants are recommended because they can lift people's mood and reduce stress and physical discomfort.

Towards a more comprehensive evidence base

The present review focused only on a selection of features of healthcare settings that are relevant to health and healing. As such, it does not provide a comprehensive overview of health benefits of healthcare settings. In particular health benefits of frequently mentioned aspects such as color, personal space, personal control, and way-finding have not been addressed. An important requirement for a more comprehensive review of health benefits of healthcare settings is a generally agreed upon taxonomy of relevant physical dimensions. In general, there are two ways in which such a taxonomy can be developed. According to a top-down approach, theoretical notions on how the environment influences health and well-being can be used to identify significant dimensions. For example, Evans & McCoy (1994) have employed the theoretical concept of psychological stress to generate a taxonomy of architectural dimensions that may affect human health. Theoretical concepts related to curing, such as the transmission of airborne pathogens, may also be useful in identifying relevant health-related architectural dimensions. According to a more bottom-up approach, architects, healthcare managers and lay people can be consulted to develop a common set of notions on health-influencing dimensions of healthcare settings.

To enhance the applicability of the evidence base to architecture and design, a taxonomy of health-influencing physical dimensions of healthcare settings should preferably use the architect's language. As every architect knows, it is not possible to design even the simplest room without making decisions on materials, textures, colors, shape, and size. Thus far, these basic architectural dimensions have received little attention in research on health impacts of built environments. The pattern language approach, in which successful design examples are compared to unsuccessful examples, may provide a useful tool for developing a common vocabulary for architects and researchers (e.g., Alexander et al., 1977).

Once a taxonomy of health-influencing dimensions of healthcare settings has become available, it is possible to conduct a further, more comprehensive review. An important advantage of such a comprehensive review would be that gaps in the existing knowledge can be identified. These knowledge gaps can be used to set an agenda for future research. Based on the findings of the present review, it is recommended that future reviews include not only clinical, but also non-clinical evidence. With respect to clinical evidence, it may be useful to make a distinction between acute and long-term care facilities. Furthermore, a clear distinction should be kept between strong and weak evidence. As with evidence-based medicine, it may even be possible to develop a 'levels-of-evidence' system to evaluate the strength of evidence. If possible, this levels-of-evidence system should also include applied research and case studies.

These recommendations represent only a few of the many challenges that are currently facing evidence-based design of healthcare settings. For the benefit of patients, visitors, and staff, it is desirable that these challenges soon be overcome and turned into solid guidelines for the architecture of healthy and healing hospitals.

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Note: The following is a list of articles, background papers, literature reviews, and other resources that are not included in the main body of evidence. The references to the research papers that fulfilled the criteria of this review are included at the end of chapters 5 & 6.

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Annex A. Summary of Papers

Nature

Viewing Nature

DeSchriver, M.M. & Riddick, C.C. (1990). Effects of watching aquariums on elders' stress. Anthrozoos, 4, 44-48.

AIM: To test the relaxation theory by having elderly persons view a live or videotaped aquarium. METHOD: 27 elderly were randomly assigned to one of three conditions: experimental group members watched a fish aquarium or a fish videotape, while control group members viewed a placebo videotape. Three eight-minute treatment sessions were held one week apart. RESULTS: Members of all three groups perceived their treatments as relaxing. Aquarium observers tended to experience a decrease in pulse rate and muscle tension and an increase in skin temperature; however these findings were not significant.

Diette, G. B., Lechtzin, N., Haponik, E., Devrotes, A., & Rubin, H.R. (2003). Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: A complementary approach to routine analgesia. Chest, 123(3), 941-948.

AIM: To determine whether distraction therapy with nature sights and sounds during flexible bronchoscopy (FB) reduces pain and anxiety. METHOD: 80 patients undergoing FB with conscious sedation were randomly assigned to one of two conditions In the experimental condition, nature scene murals were placed at the bedside, and patients were provided a tape of nature sounds to listen to before, during, and after the procedure. Patients assigned to the control group were not offered either the nature scene or the sounds. RESULTS: In a multivariate ordinal logistic regression model, the odds of better pain control were greater in the intervention patients than in the control patients, after adjustment for age, gender, race, education, health status, and dose of narcotic medication. Older patients and patients with better health status reported significantly less pain. There was no difference in self-reported anxiety between the two groups. CONCLUSION: Distraction therapy with nature sights and sounds significantly reduces pain in patients undergoing FB.

Edwards, N., & Beck, A. (2002). Animal-assisted therapy and nutrition in Alzheimer's Disease. Western Journal of Nursing Research, 24, 697-712.

AIM: This study examined the influence of fish aquariums on nutritional intake in individuals with Alzheimer's disease (AD). METHOD: Sixty-two individuals with AD who lived in specialized units were studied. Baseline nutritional data were obtained followed by a 2-week treatment period when the aquariums were introduced. The treatment data were collected daily for 2 weeks then weekly for 6 weeks. RESULTS Nutritional intake increased with 21% when the aquariums were introduced and continued to increase during the 6-week weekly follow-up. Weight increased significantly over the 16-week period. In addition, participants required less nutritional supplementation, resulting in health care cost savings.

Faber Taylor, A., Kuo, F.E., & Sullivan, W.C. (2002). Views of nature and self-discipline: evidence from inner city childeren. Journal of Environmental Psychology, 22, 49-63.

AIM: To examine the relationship between near-home nature and self-discipline. METHOD: 169 inner city girls and boys in 12 architecturally identical high-rise buildings with varying levels of nearby nature were compared with respect to their self-discipline. Parent ratings of the naturalness of the view from home were related to children's performance on tests of concentration, impulse inhibition, and delay of gratification. RESULTS: Regressions indicated that, on average, the more natural a girl's view from home, the better her performance at each of these forms of self-discipline. For boys, who typically spend less time playing in and around their homes, view from home showed no relationship to performance on any measure. CONCLUSION: These findings suggest that, for girls, green space immediately outside the home can help them lead more effective, self-disciplined lives. For boys, perhaps more distant green spaces are equally important.

Fredrickson, B.L., & Branigan, C. (in press, Study 1 & 2). Positive emotions broaden the scope of attention and thought-action repertoires. Cognition and Emotion.

AIM: To test the broaden-and-build theory (Fredrickson, 1998, 2001) which hypothesizes that positive emotions broaden the scope of attention and thought-action repertoires. METHOD: Two experiments with 104 college students were conducted. In each, participants viewed a film that elicited (a) amusement, (b) contentment, (c) neutrality, (d) anger, or (e) anxiety. Scope of attention was assessed using a global-local visual processing task (Experiment 1) and thought-action repertoires were assessed using a Twenty Statements Test (Experiment 2). RESULTS: Compared to a neutral state, positive emotions elicited by short films of penguins and nature broadened the scope of attention in Experiment 1 and thought-action repertoires in Experiment 2. In Experiment 2, negative emotions, relative to a neutral state, narrowed thought-action repertoires.

Fredrickson, B.L., & Levenson, R.W. (1998, Study 1). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. Cognition and Emotion, 12, 191-220.

AIM: To test the hypothesis that certain positive emotions speed recovery from the cardiovascular sequelae of negative emotions. METHOD: In Study 1, 60 subjects viewed an initial fear-eliciting film, and were randomly assigned to view a secondary film that elicited: (a) contentment; (b) amusement; (c) neutrality; or (d) sadness. RESULTS: Compared to subjects who viewed the neutral and sad secondary films, those who viewed the positive films showing a puppy and waves exhibited more rapid returns to pre-film levels of cardiovascular activation. COMMENT: This paper also includes a second study that is irrelevant to health benefits of nature.

Hartig, T., Böök, A., Garvill, J., Olsson, T. & Gärling, T. (1996, Study 1). Environmental influences on psychological restoration. Scandinavian Journal of Psychology, 37, 378-393.

AIM: To test environmental influences on psychological restoration. METHOD: 102 students were randomly assigned to one of three conditions: viewing slides of nature, slides of built environments, or no slides. In each condition, half of the subject performed mentally fatiguing task before watching the film RESULTS: Compared to the control groups, groups who viewed the natural environment simulation engendered generally more positive emotional self-reports. Consistent performance effects were not found which suggests that attentional restoration as reflected in performance is a more time-intensive process. COMMENT: This paper also includes a second study that does not meet the criteria for inclusion in this review.

Kuo, F.E. (2001). Coping with poverty: Impacts of environment and attention in the inner city. Environment & Behavior, 33(1), 5-34.

AIM: To investigate whether exposure to green environments can enhance human effectiveness and make life's demands in poor inner cities seem manageable. METHOD: 145 female residents of buildings with and without nearby nature were compared with respect to attentional functioning and effectiveness in managing major life issues. RESULTS: Residents living in buildings with nearby trees and grass reported better functioning in life, and performed better on a concentration task than did their counterparts living in barren surroundings. Mediation tests showed that better life functioning in green surroundings could be explained by better ability to concentrate. CONCLUSION: These findings suggest that urban public housing environments can be configured to enhance residents' psychological resources for coping with poverty.

Kaplan, R. (2001). The nature of the view from home: Psychological benefits. Environment and Behavior, 33, 507-542.

AIM: To test the notion that looking out the window may provide numerous opportunities for restoration. METHOD: A survey with both verbal and visual information among 188 residents of six low-rise apartment communities. RESULTS: Having natural elements or settings in the view from the window contributes substantially to residents' satisfaction with their neighborhood and with diverse aspects of their sense of well-being. Views of built elements, by contrast, affected satisfaction but not well-being. Views of the sky and weather did not have a substantial effect on either outcome. CONCLUSION: The potential of nature content in the view from home to contribute so significantly to satisfaction and well-being suggests clear action mandates.

Laumann, K., Gärling, T., & Stormark, K.M. (2003). Selective attention and heart rate responses to natural and urban environments. Journal of Environmental Psychology, 23, 125-134.

AIM: To test the hypothesis that exposure to nature stimuli restores depletes voluntary attention capacity and affects selective attention METHOD: 28 subjects first completed a proofreading task to induce mental load and then performed Posner's attention-orienting task before and after viewing a video of either a natural or an urban environment. Cardiac inter-beat interval (IBI) was measured continuously to index autonomic arousal. RESULTS: Before the video both groups reacted faster to validly versus invalidly cued targets in the attention-orienting task. After the video, the urban group was still faster on validly versus invalidly cued trials, but in the nature group this difference disappeared. During the video the nature group had a lower heart rate measured as the difference from baseline than the urban group. CONCLUSION: The results suggest that reduced autonomic arousal during the video engendered less spatially selective attention in the nature group compared to the urban group.

Miller, A.C., Hickman, L.C., & Lemasters, G.K. (1992). A distraction technique for control of burn pain. Journal of Burn Care and Rehabilitation, 13(5), 576-580.

AIM: The purpose of this study was to determine the effects of a distraction therapy, in which videos were used in combination with administration of analgesics, on intensity and quality of pain and on levels of anxiety. METHOD: 17 patients undergoing burn dressing changes were randomly assigned to the treatment or the control group. The treatment group viewed video programs that were composed of nature scenes accompanied by music. Each was asked to score his or her present pain intensity and pain rating index with the McGill questionnaire and anxiety with the Spielberger questionnaire before and after the dressing change. RESULTS: A nested general linear model, adjusted for age, percent partial-thickness burn, and choice of topical agent, demonstrated that the use of videos during the dressing changes significantly reduced pain and anxiety

Parsons, R., Tassinary, L.G., Ulrich, R.S., Hebl, M.R., Grossman-Alexander, M. (1998). The view from the road: Implications for stress recovery and immunization. Journal of Environmental Psychology, 18, 113-140.

AIM: To examine whether stress recovery and/or immunization varies as a function of the roadside environment. METHOD: 160 students viewed one of four different video-taped simulated drives through outdoor environments immediately following and preceding mildly stressful events. RESULTS: Participants who viewed nature dominated drives (in particular drives through a golf course), as compared to participants who viewed artifact-dominated drives, showed less autonomic activity indicative of stress (e.g., elevated blood pressure and electrodermal activity), as well as altered somatic activity indicative of a decrease in negative affect (e.g., elevated electromyographic (EMG) activity over the brow region and decreased activity over the cheek region). In addition, participants who viewed nature-dominated drives experienced quicker recovery from stress and greater immunization to subsequent stress than participants who viewed artifact-dominated drives. CONCLUSION: These findings support a sympathetic-specific mechanism that underlies the effect of nature on stress recovery and immunization.

Schneider, S.M., Ellis, M., Coombs, W.T., Shonkwiler, E.L., & Folsom, L.C. (2003). Virtual reality intervention for older women with breast cancer. Cyberpsychology & Behavior, 6(3), 301-307.

AIM: This study examined the effects of a virtual reality distraction intervention on chemotherapy-related symptom distress levels. METHOD: 16 women aged 50 and older were randomly assigned to receive the VR distraction intervention (using a head-mounted display) during one chemotherapy treatment and received no distraction intervention (control condition) during an alternate chemotherapy treatment. The Symptom Distress Scale (SDS), Revised Piper Fatigue Scale (PFS), and the State Anxiety Inventory (SAI) were used to measure symptom distress. For two matched chemotherapy treatments, one pre-test and two post-test measures were employed. RESULTS: Analysis using paired t-tests demonstrated a marginally significant decrease in the SAI ($p = 0.10$) scores immediately following chemotherapy treatments when participants used VR. No significant changes were found in SDS or PFS values. There was a consistent trend toward improved symptoms on all measures 48 h following completion of chemotherapy.

Schneider, S.M., Prince-Paul, M., Allen, M.J., Silverman, P., & Talaba, D. (2004). Virtual reality as a distraction intervention for women receiving chemotherapy. Oncology Nursing Forum, 31(1), 81-88.
AIM: To explore the use of virtual reality as a distraction intervention to relieve symptom distress in women receiving chemotherapy for breast cancer. METHOD: Using a crossover design, 20 adult subjects served as their own controls. For two matched chemotherapy treatments, one pretest and two post-test measures were employed. Participants were assigned randomly to receive the a virtual reality distraction intervention consisting of images of nature during one chemotherapy treatment and received no distraction intervention (control condition) during an alternate chemotherapy treatment. An open-ended questionnaire elicited each subject's evaluation of the intervention. RESULTS: Significant decreases in symptom distress and fatigue occurred immediately following chemotherapy treatments when women used the virtual reality intervention. CONCLUSIONS: The distraction intervention decreased symptom distress, was well received, and was easy to implement in the clinical setting.

Tennessen, T.M. & Cimprich, B. (1995). Views to nature: effects on attention. Journal of Environmental Psychology, 15, 77-85.
AIM: The purpose of this study was to explore whether university dormitory residents with more natural views from their windows would score better than those with less natural views on tests of directed attention. METHOD: Views from dormitory windows of 72 undergraduate students were categorized into four groups ranging from all natural to all built. The capacity to direct attention was measured using a battery of objective and subjective measures. RESULTS: Natural views were associated with better performance on attentional measures.

Tse, M.M.Y., Ng, J.K.F., Chung, J.W.Y., & Wong, T.K.S. (2002a). The effect of visual stimuli on pain threshold and tolerance. Journal of Clinical Nursing, 11(4), 462-469.
AIM: To investigate the therapeutic potential of visual stimulation as a nursing intervention. METHOD: In a randomized, controlled, cross-over study, pain was produced by a modified tourniquet technique in 46 healthy volunteers. Subjects were randomly allocated to two groups with subsequent cross-over. Those in the experimental group watched a soundless video display of natural scenery during tourniquet inflation, whereas control group subjects watched a static blank screen. RESULTS: With the use of visual stimuli, there was a significant increase in pain threshold and pain tolerance. Gender and the sequence of visual stimuli did not have any significant effect on pain threshold and pain tolerance.

Tse, M.M.Y., Ng, J.K.F., Chung, J.W.Y., & Wong, T.K.S. (2002b). The effect of visual stimulation via the eyeglass display and the perception of pain. Cyberpsychology & Behavior, 5(1), 65-75.
AIM: To study the effectiveness of an eyeglass display to block off the anxiety-inducing sights and sounds of the hospital surroundings and create a pleasant environment. METHOD: In this randomized, controlled, crossover study, 72 healthy university student volunteers were asked to wear a light-weight eyeglass that projected a feeling of watching a 52-inch television screen at 6 1/2 feet in distance while pain was produced by a modified tourniquet technique. Subjects were randomly assigned to participate in an experimental or control session first, with

subsequent cross-over. In an experimental session, subjects were instructed to wear the eyeglass and watch the soundless display of natural scenery during the inflation. In a control session, the eyeglass that subjects wore would project a static blank screen. RESULTS: During experimental sessions, there was a significant increase in pain threshold and pain tolerance. The degree of fascination was positively correlated with improvement in pain threshold, whereas the anxiety level was negatively correlated with improvement in pain threshold.

Ulrich, R. (1979). Visual landscapes and psychological well-being. Landscape research, 4, 17-23.

AIM: To study effects of viewing nature on mood. METHOD: The basic design of the experiment involved showing colored slides of outdoor environments to a sample of 46 mildly stressed subjects. One group viewed 50 slides of unspectacular nature scenes dominated by green vegetation. The other group viewed 50 urben scenes lacking natural elements. The affect states or feelings of the subjects, defined primarily in terms of anxiety emotions, were measured both immediately before and after the slide exposures. RESULTS: The findings suggest that stressed individuals feel significantly better after exposure to nature scenes rather than to American urban scenes lacking nature elements. Compared to the influences of the urban scenes, the salient effect of the nature exposures was to increase positive affect - including feelings of affection, friendliness, playfulness, and elation.

Urich, R.S. (1984) View through a window may influence recovery from surgery. Science, 224, 420-421.

AIM: To study relationships between views of nature and recovery from surgery. METHOD: Records on recovery after cholecystectomy of 46 patients in a suburban Pennsylvania hospital between 1972 and 1981 were examined to determine whether assignment to a room with a window view of a natural setting might have restorative influences. RESULTS: Patients assigned to rooms with windows looking out on a natural scene had shorter postoperative hospital stays, received fewer negative evaluative comments in nurses' notes, and took fewer potent analgesics than matched patients in similar rooms with windows facing a brick building wall.

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology, 11, 201-230.

AIM: To test the hypothesis that if individuals are stressed, an encounter with most unthreatening natural environments will have a stress reducing or restorative influence, whereas many urban environments will hamper recuperation. METHOD: 120 subjects first viewed a stressful movie, and then were exposed to color/sound videotapes of one of six different natural and urban settings. Data concerning stress recovery during the environmental presentations were obtained from self-ratings of affective states and a battery of physiological measures: heart period, muscle tension, skin conductance and pulse transit time, a non-invasive measure that correlates with systolic blood pressure. RESULTS: Findings from the physiological and verbal measures converged to indicate that recovery was faster and more complete when subjects were exposed to natural rather than urban environments. There was no evidence of pronounced parasympathetic involvement in responses to the urban settings. Both the stressor film and the nature settings elicited high levels of involuntary or automatic attention, which contradicts the notion that restorative influences of nature stem from involuntary attention or fascination.

CONCLUSION: Findings were consistent with the predictions of the psycho-evolutionary theory that restorative influences of nature involve a shift towards a more positively-toned emotional state, positive changes in physiological activity levels, and that these changes are accompanied by sustained attention/intake.

Ulrich, R.S., Simons, R.F., & Miles, M.A. (2003). Effects of environmental simulations and television on blood donor stress. Journal of Architectural & Planning Research, 20(1), 38-47.

AIM: To study whether stress in patients undergoing a procedure known to be stressful - blood donation - is affected by modest changes in a clinic environment. METHOD: Four different environmental conditions were presented to 872 blood donors using wall-mounted television monitors: a videotape of nature settings (Nature); a tape of urban environments (Urban); daytime television (Television); or a blank monitor (No Television). RESULTS: Blood-pressure and pulse-rate findings converged to indicate that stress was lower during No Television than Television, and during Low Stimulation (No Television + Nature) than High Stimulation (Television + Urban). Pulse rates were markedly lower during Nature than Urban. CONCLUSION: An important clinical implication of the findings is that the common practice of playing uncontrollable daytime television in healthcare waiting areas where stress is a problem may actually have stressful, not stress-reducing influences on many patients/consumers.

Van den Berg, A.E., Koole, S.L., & Van der Wulp, N.Y. (2003). Environmental preference and restoration: (How) are they related? Journal of Environmental Psychology, 23, 135-146

AIM: To test whether the widely documented tendency to prefer natural over built environments is mediated by the greater restorative potential of natural environments. METHOD: 114 participants viewed a frightening movie, and then were shown a video of either a natural or a built environment. Participants' mood ratings were assessed before and after they viewed the frightening movie, and again after viewing the environmental video. Participants also rated the beauty of the environment shown (to indicate preference) and performed a test of concentration after viewing the environmental video. RESULTS: The results indicate that participants perceived the natural environments as more beautiful than the built environments. In addition, viewing natural environments elicited greater improvement in mood and marginally better concentration than viewing built environments. Mediational analyses revealed that affective restoration accounted for a substantial proportion of the preference for the natural over the built environments. CONCLUSION: These results substantiate the adaptive function of people's environmental preferences.

Gardens/Being in nature

Cimprich, B. & Ronis, D. (2003). An environmental intervention to restore attention in women newly diagnosed with breast cancer. Cancer Nursing 26(4), 284-292.

AIM: This study tested the efficacy of a natural environment intervention aimed at restoring attention. METHOD: 157 women with newly diagnosed breast cancer were assessed for their capacity to direct attention with a brief battery of objective measures at two time points: approximately 17 days before surgery (time 1) and 19 days after surgery (time 2). A randomly assigned intervention protocol was initiated after the first assessment and before any treatment. The intervention comprised a home-based program involving 120 minutes of exposure to the natural environment per week. RESULTS: The intervention group (n = 83) showed greater recovery of capacity to direct attention from the pretreatment (time 1) to the preadjuvant therapy period (time 2), as compared with the nonintervention group (n = 74). A significant effect of the natural environment intervention was observed even after control was used for the effects of age, education, attention scores at time 1, other health problems, symptom distress, and extent of surgery. CONCLUSION: The findings suggest therapeutic benefits for capacity to direct attention from early intervention aimed at restoring attention in women with newly diagnosed breast cancer.

Hartig, T., Evans, G.W., Jamner, L.D., Davis, D.S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. Journal of Environmental Psychology, 23, 109-123.

AIM: To compare psychophysiological stress recovery and directed attention restoration in natural and urban field settings. METHOD: Repeated measures of ambulatory blood pressure, emotion, and attention were collected from 112 randomly assigned young adults. To vary restoration needs, half of the subjects began the environmental treatment directly after driving to the field site. The other half completed attentionally demanding tasks just before the treatment. RESULTS: After the drive or the tasks, sitting in a room with tree views promoted more rapid decline in diastolic blood pressure than sitting in a viewless room. Subsequently walking in a nature reserve initially fostered blood pressure change that indicated greater stress reduction than afforded by walking in the urban surroundings. Performance on an attentional test improved slightly from the pretest to the midpoint of the walk in the nature reserve, while it declined in the urban setting. Positive affect increased and anger decreased in the nature reserve by the end of the walk; the opposite pattern emerged in the urban environment. The task manipulation also affected emotional self-reports.

Hartig, T., Mang, M., & Evans, G.W. (1991, Study 1 & 2). Restorative effects of natural environment experience. Environment and Behavior, 23, 3-26.

AIM: To investigate the utility of different theoretical models of restorative experience. METHOD: Restorative effects of nature were investigated in a quasi-experimental field study and a true experiment. The former included wilderness backpacking and nonwilderness vacation conditions, as well as a control condition in which participants continued with their daily routines. The latter had urban environment, natural environment, and passive relaxation conditions. Assessments of restoration consisted of self-reports of affective states, cognitive performance, and, in the latter study, physiological measures. RESULTS: Convergent self-report and performance results obtained in both studies offer evidence of greater restorative effect arising from experiences in nature.

Takano, T., Nakamura, K., & Watanabe, M. (2003). Urban residential environments and senior citizens' longevity in megacity areas. The importance of walkable green spaces. Journal of Epidemiological Community Health, 56, 913-918.

AIM: To study the association between public greenery nearby a residence and the longevity of senior citizens in the densely populated city of Tokyo. METHOD: A cohort study analyzed the five year survival of 3144 people born in

1903, 1908, 1913, or 1918 who consented to a follow up survey from the records of registered Tokyo citizens in relation to baseline residential environment characteristics in 1992. RESULTS: The survival of 2211 and the death of 897 (98.9% follow up) were confirmed. The probability of five year survival of the senior citizens studied increased in accordance with the space for taking a stroll near the residence, parks and tree lined streets near the residence, and their preference to continue to live in their current community. CONCLUSION: Living in areas with walkable green spaces positively influenced the longevity of urban senior citizens independent of their age, sex, marital status, baseline functional status, and socioeconomic status.

Indoor plants

Adachi, M., Rohde, C.L.E., & Kendle, A.D. (2000). Effects of floral and foliage displays on human emotions. HortTechnology. 10, 59-63.

AIM: To investigate changes in human emotions during exposure to floral and foliage displays. METHOD: 20 subjects (10 males and 10 females) were randomly assigned to one of three conditions: floral display present, foliage display present, and no display present. The subjects were shown a video that introduced the University of Reading and included scenes of landscapes. It was shown that a floral display had positive effects on human emotions, such as composition and confidence, however, some evidence of a significant increase in annoyance was also found for this treatment. The foliage display had a somewhat negative effect by slightly increasing bad temper, and the foliage display tended to have a positive effect on clearheadedness.

Fjeld, T. (2000, Study 2 & 3) The effect of interior planting on health and discomfort among workers and school children. HortTechnology. 10, 46-52.

AIM: To assess the effect of foliage plants or a combination of foliage plants and full-spectrum fluorescent lamps on self-reported health and discomfort complaints. METHOD: Self-reported health and discomfort complaints of 48 workers in an X-ray department in a Norwegian hospital, and 120 pupils of a junior high school. were assessed periods with and without plants and full-spectrum lights RESULTS: Health and discomfort symptoms were found to be 21% to 25% lower during the period when subjects had plants or plants and full-spectrum lighting present compared to a period without plants. Neuropsychological symptoms, such as fatigue and headache, and mucous membrane symptoms, such as dry and hoarse throat, seemed to be more affected by the treatments than skin symptoms, such as itching skin. COMMENT: This paper also describes a study among office workers (Study 1) which is reported in more detail in Fjeld et al. (1998).

Fjeld, T., Veiersted, B., Sandvik, L., Riise, G., & Levy, F. (1998). The effect of indoor foliage plants on health and discomfort symptoms among office workers. Indoor and Built Environments, 7, 204-09.

AIM: To assess the effect of foliage plants in the office on health and symptoms of discomfort among office personnel. METHOD: A cross-over study with randomized period order was conducted; one period with plants in the office and one period without. A questionnaire consisting of 12 questions related to neuropsychological symptoms, mucous membrane symptoms and skin symptoms was distributed among the 51 healthy subjects who participated in the study. RESULTS: The score sum of symptoms was 23% lower during the period when subjects had plants in their offices compared to the control period. Complaints regarding cough and fatigue were reduced by 37 and 30%, respectively, if the offices contained plants. The self-reported level of dry/hoarse throat and dry/itching facial skin each decreased approximately 23% when plants were present. Overall, a significant reduction was obtained in neuropsychological symptoms and mucous membrane symptoms, while skin symptoms seemed to be unaffected by the presence of plants. CONCLUSION: The results from this study suggest that an improvement in health and a reduction in symptoms of discomfort may be obtained after introduction of foliage plants into the office environment. COMMENT: This Study is also described in Fjeld (2000).

Giese, M., U., Bauer-Doranth, Langebartels, C., & Sandermann, H. (1994) Detoxification of formaldehyde by the spider plant (Chlorophytum comosum L.) and by soybean (Glycine max L.) cell suspension cultures. Plant Physiology, 104:1301-1309.

AIM: To assess detoxification of formaldehyde by plants. METHOD: Shoots of spider plants soybean were exposed to [14C]-formaldehyde over 24 h. RESULTS: Approximately 88% of the recovered radioactivity was plant associated and was found to be incorporated into organic acids, amino acids, free sugars, and lipids as well as cell-wall components. Serine and phosphatidylcholine were identified as major metabolic products. CONCLUSION: The results obtained are consistent with the concept of indoor air decontamination with common room plants such as the spider plant Formaldehyde appears to be efficiently detoxified by oxidation and subsequent C1 metabolism.

Larsen, L. , Adams, J., Deal, B., Kweon, B.S., & Tyler, E. (1998). Plants in the workplace: The effects of plant density on productivity, attitudes, and perceptions. Environment and Behavior, 30, 261-281.

AIM: To study the effects of indoor plants on participants' productivity, attitude toward the workplace, and overall mood in the office environment. METHOD: In an office randomly altered to include no plants, a moderate number of plants, and a high number of plants, 81 paid participants performed timed productivity tasks and completed a survey questionnaire. RESULTS: The results of the productivity task show an inverse linear relationship to the number of plants in the office, but self-reported perceptions of performance increased relative to the number of plants in the office. Subjects reported higher levels of mood, perceived office attractiveness, and (in some cases) perceived comfort when plants were present than when they were not present. Decreased productivity scores were linked to the influence of positive and negative affect on decision making and cognitive processing.

Lohr, V.I., & Pearson-Mims, C.H. (2000). Physical discomfort may be reduced in the presence of interior plants. HortTechnology, 10, 53-58.

AIM: To examine the role of plants in pain tolerance. METHOD: 198 subjects were randomly assigned to one of three conditions: a room with plants, a room with equally distracting colorful objects, and a room without plants. They were asked to hold their hand in ice water RESULTS: More subjects were willing to keep a hand submerged in ice water for 5 min if they were in a room with plants present than if they were in a room without plants or colorful objects. Results from a room assessment survey confirmed that the room with colorful, nonplant objects was as interesting and colorful as the room with plants present, but the presence of plants was perceived as making the air in the room fresher.

Lohr, V.I., Pearsons-Mims, C.H., & Goodwin, G.K. (1996). Interior plants may improve worker productivity and reduce stress in a windowless environment. Journal of Environmental Horticulture, 14, 97-100.

AIM: To study the effect of plants on productivity and stress in a windowless office. METHOD Subjects were randomly assigned to be tested in a computer lab at Washington State University when plants were absent or when they were present. Interior plants, when present, were placed around the sides of the room. Subjects' blood pressure and emotions were monitored while they performed a slightly stressful computer task that measured reaction times in response to seeing and decoding the shape of a simple object on the screen. RESULTS: When plants were added to the lab, the subjects were more productive (12% quicker reactions on the computer task) and less stressed (systolic blood pressure lower). They also reported feeling more attentive when the plants were present.

Oyabu, T., Sawada, A. Hashimoto, T., & Yoshioka, T. (2004, Study 1 & 2). Removing characteristic of indoor air pollutants according to activated carbon pot and plant using a tin oxide gas sensor. Electrochemistry in Japan, 12, 813-817.

AIM: To examine the capability of plants to absorb chemical substances in the air. METHOD: In Study 1, an interior plant pot was made of the activated carbon and installed in an experimental chamber. In Study 2, three pots were installed in a real office room and examined for their removing capability. In the room, formaldehyde was emitted continuously and the saturated concentration was almost constant. RESULTS: In Study 1, the pot could entirely absorb the formaldehyde of about 6.5 ppm in five hours. It also had a removing capability to larger molecular weight chemicals, for example toluene and xylene. In Study 2, the concentration of formaldehyde was decreased to 60% by installing the pots. CONCLUSION: Plants have a high removing capability to absorb formaldehyde in experimental chambers and real office room.

Oyabu, T., Onodera, T. Kimura, H. et al (2001). Purification ability of interior plants for removing of indoor air polluting chemicals using a tin oxide gas sensor. Journal of Japan Society for Atmospheric Environment, 34, 319-325.

AIM: To study the purifying ability of house-plants METHOD: The removal rate of indoor air pollutants from an experimental sealed chamber by house plants (Golden pothos) was examined. Pa was derived from tin oxide gas-sensor characteristics for a chemical. Pa is the value of which the peak of the characteristic is divided by the full-width at half maximum. The smaller the molecular weight of a chemical is, the larger Pa becomes. The following chemicals were examined; formaldehyde, toluen, xylene, cigarette smoke and car exhaust. RESULTS: The Pa of Golden pothos was 25 for formaldehyde, and 80 for ammonia gas.

Russel, H. (1999). The psychological effects of plants on people in offices. Interiorscape, 19-21.

AIM: This study tested whether the presence of plants in a room affected the stress levels of people undertaking a complex test. METHOD: Participants in the study were invited to an office that had no plants or was heavily planted. Sensors were attached to the skin of the participants to record skin conductivity, heart rate and blood pressure. A base line recording of stress levels was recorded during a period of 10 minutes, in which participants could get used to their surrounding. After this 10 minute period, the participants were asked to add up a list of 78 numbers without using their fingers or counting aloud. During the test, additional distractors, such as the sound of a ringing telephone or traffic noise, were played to them at random intervals. After the test, a further 10-minute period of rest was allowed. RESULTS: Of the three types of measurements, skin conductivity showed the greatest difference between the group exposed to plants and the group in the unplanted office. The results showed that, for this measurement, stress was reduced in the planted office. The other tests showed very little difference between the two situations. The results also showed that those people in the planted office recovered from their stress more quickly than those in the unplanted office during the 10-minute post-test rest period.

Shibata, S. & Suzuki, N. (2002). Effects of the foliage plant on task performance and mood. Journal of Environmental Psychology, 22, 265-272.

AIM: To investigate the effect of leafy plants on subjects' task performance and mood. METHOD: 146 undergraduate students performed an association task or sorting task under one of three room arrangements (plants in front of subjects, to the side of subjects, or no plants). The association task was to create no more than 30 words for 20 different items. The sorting task was to sort 180 index cards into Japanese syllabary order. RESULTS: Task performances of the male subjects using the front arrangement were higher than that of the male subjects working without plants. CONCLUSION: It was concluded that the presence of the plants affected the association task more than the sorting task, and male subjects more than female subjects. It was also suggested that the presence of the leafy plants might affects creative work positively.

Wolverton, B.C., McDonald, R.C., & Watkins, Jr., E.A. (1984) Foliage plants for removing indoor air pollutants from energy-efficient homes. Economic Botany 224-228.

AIM: To evaluate the ability of foliage plants to remove formaldehyde from contaminated air. METHOD: Golden pothos (Scindapsus aureus), nephthytis (Syngonium podophyllum) and spider plant (Chlorophytum elatum var. vittatum) were placed in a sealed, Plexiglas chamber with temperature and humidity control and illuminated externally with wide spectrum grow lights. RESULTS: The spider plant proved most efficient by sorbing and/or effecting the removal of up 2.27 mug formaldehyde/cm^2 leaf surface area in 6 h of exposure. CONCLUSION: The immediate application of this new botanical air-purification system should be in energy-efficient homes that have a high risk of this organic concentrating in the air, due to outgassing of urea-formaldehyde foam insulation, particleboard, fabrics and various other synthetic materials.

Wolverton, B.C., McDonald, R.C. & Mesick, H.H. (1985). Foliage plants for the indoor removal of the primary combustion gases carbon monoxide and nitrogen oxides. Journal of the Mississippi Academy of Sciences, 30, 1-8.

AIM: To evaluate the ability of foliage plants to sorb carbon monoxide and nitrogen dioxide, the two primary gases produced during the combustion of fossil fuels and tobacco. METHOD: Plants were placed in sealed chambers. RESULTS: The spider plant (*Chlorophytum elatum var. vittatum*) could sorb 2.8 µg CO/cm^2 leaf surface in a 6 h photoperiod. The golden photos (*Scindapsus aureus*) sorbed 0.9µg CO/cm^2 leaf surface in the same time period. In a system with the spider plant, ≥ 99% of an initial concentration of 47 ppm NO2 could be removed in 6 h from a void volume of approximately 0.35 m^3. One spider plant posted in a 3.8 liter container can sorb 3300 µg CO and effect the removal of 8500 µg NO2 per hour, recognizing the fact that a significant fraction of NO2 at high concentrations will be lost by surface sorption, dissolving in moisture, etc.

Wolverton, B.C. & Wolverton, J.D. (1993). Plants and soil microorganisms: Removal of formaldehyde, xylene and ammonia from the indoor environment. Journal of the Mississippi Academy of Sciences, 38, 11-15.

AIM: To study the ability of interior plants in potting soil and potting soil without plants to remove formaldehyde, xylene, and ammonia. METHOD: Plants and soil were placed in sealed chambers. RESULTS: Over thirty interior plants were tested and *Nephrolepis exaltata "Bostoniensis"* (Boston fern), *Chrysanthemum morifolium* (pot mum), and *Phoenix roebelenii* (dwarf date palm) were the most effective in removing formaldehyde. The dwarf palm date was the most effective plant in removing xylene. Lady palm was one of the most effective plants in removing ammonia. The Boston fern was also the most effective plant in continuously removing out-gassing formaldehyde from particle board in a sealed chamber. CONCLUSION: This data indicates that house plants such as ferns, pot mums, and palms may be a cost effective means of improving the indoor air quality in tightly constructed facilities ranging from mobile homes to high-rise office facilities.

Wolverton, B.C. & Wolverton, J.D. (1996). Interior plants: Their influence on airborne microbes inside energy-efficient buildings. Journal of the Mississippi Academy of Sciences, 41, 99-105.

AIM: This study addresses the influence of large numbers of houseplants on airborne microbial levels inside energy-efficient buildings. METHOD: Parts of a tightly sealed, energy-efficient home located in South Mississippi served as "real world" test chambers. A plant-filled sunroom and adjacent living room were tested in two studies, each three months in duration and at different times of the year. A plant-free bedroom, located in another section of the home, served as a control. RESULTS: Although humidity levels in the plant filled sunroom were higher than the plant-free bedroom, airborne microbial levels were found to be more than fifty percent higher in the plant-free bedroom. CONCLUSION: These findings indicate that houseplants are influencing the level of microbes in air where large numbers of plants are grown.

Natural elements

Daylight

Baron, R.A., Rea, M.S., & Daniels, S.G. (1992, experiment 1). Effects of indoor lighting (illuminance and spectral distribution) on the performance of cognitive tasks and interpersonal behaviors: The potential mediating role of positive affect. Motivation and Emotion, 16, 1-33.

AIM: To examine the effects of key aspects of indoor lighting on the performance of tasks that did not primarily involve visual processing. METHOD: 3 studies with 243 undergraduates were conducted. Experiment 1 included full-spectrum light to other types of lamps. RESULTS: In experiment 1, full-spectrum light was not associated with positive affect, nor did it produce the best performance or social behavioral results. Across the 3 investigations, variations in 2 aspects of indoor lighting (illuminance and lamp color) were found to exert significant effects on (1) evaluations of a fictitious employee, (2) word categorization, (3) preference for resolving interpersonal conflicts through collaboration vs avoidance, (4) reported expected ability to perform a clerical task, and (5) willingness to offer help to others. In addition, subjects reported contrasting subjective reactions to the experimental rooms and to the lighting conditions in them under varying combinations of illuminance and color.

Beauchemin, K.M., & Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. Journal of Affective Disorders, 40(1), 49-51.

AIM: To study the effectiveness of sunlight in hospital rooms as a treatment for seasonal affective disorder. METHOD: The lengths of stay of depressed patients in sunny rooms of a psychiatric inpatient unit were compared with those of patients in dull rooms. RESULTS: Those in sunny rooms had an average stay of 16.9 days compared to 19.5 days for those in dull rooms, a difference of 2.6 days (15%).

Beauchemin, K.M., & Hays, P. (1998). Dying in the dark: Sunshine, gender and outcomes in myocardial infarction. Journal of the Royal Society of Medicine, 91(7), 352-354.

AIM: To examine the possibility that sunny rooms are conducive to better outcomes. METHOD: The sample consisted of 628 patients admitted directly to the CICU with a first attack of myocardial infarction (MI). Outcomes of those treated in sunny rooms and those treated in dull rooms were retrospectively compared for fatal outcomes and for length of stay in the CICU. RESULTS: Patients stayed a shorter time in the sunny rooms, but the significant difference was confined to women (2.3 days in sunny rooms, 3.3 days in dull rooms). Mortality in both sexes was consistently higher in dull rooms (39/335 dull, 21/293 sunny).

Benedetti, F., Colombo, C., Barbini, B., Campori, E., & Smeraldi, E. (2001). Morning sunlight reduces length of hospitalization in bipolar depression. Journal of Affective Disorders, 62(3), 221-223.

AIM: To study the impact of sunlight on non-seasonal depression. METHOD: Length of hospitalization was recorded for a sample of 415 unipolar and 187 bipolar depressed inpatients, assigned to rooms with eastern or western windows. RESULTS: Bipolar inpatients in eastern rooms (exposed to direct sunlight in the morning) had a mean

3.67-day shorter hospital stay than patients in western rooms. No effect was found in unipolar inpatients. CONCLUSIONS: Natural sunlight can be an underestimated and uncontrolled light therapy for bipolar depression.

Boray, P.F., Gifford, R., & Rosenblood, L. (1989). Effects of 'warm' white, 'cool' white, and full-spectrum fluorescent lighting on simple cognitive performance, mood and ratings of others. Journal of Environmental Psychology, 9, 297-308.

AIM: To investigate the effects of lighting conditions on cognitive performance, mood and ratings of others. METHOD: 117 university students were randomly assigned to conditions of warm white, cool white, and full-spectrum fluorescent spectra lighting at approximately equal illuminances . Dependent measures included simple verbal and quantitative tasks, salary recommendations, rated attractiveness and friendliness of others, judged room attractiveness, estimated room size, and self-reported pleasure and arousal. RESULTS: No significant differences were found among the 3 lighting types on any of the dependent measures. A subsequent power analysis indicated that if differences do exist, they are quite small. CONCLUSION: Cool white or warm white lamps are recommended as less expensive alternatives to full-spectrum lamps.

Knez, I. (1995, Study 1 & Study 2). Effects of indoor lighting on mood and cognition. Journal of Environmental Psychology, 15, 39-51.

AIM: To study the effect of indoor lighting on cognitive performance via mood. METHOD: Experiment 1 varied two lighting parameters in a factorial, between-subject design: two illuminance levels (dim; 300 lx vs bright; 1500 lx) by two colour temperatures ('warm' white; 3000K vs 'cool' white; 4000K) at high CRI (Colour Rendering Index; 95). In experiment 2 the parameters of lighting were identical to the first experiment, except for the low CRI (CRI; 55). RESULTS: In experiment 1 it was found that a color temperature which induced the least negative mood enhanced the performance in the long-term memory and problem-solving tasks, in both genders. In experiment 2, the combination of color temperature and illuminance that best preserved the positive mood in one gender enhanced this gender's performance in the problem-solving and free recall tasks. CONCLUSION: Subjects' mood valences and their cognitive performances varied significantly with the genders' emotionally different reactions to the indoor lighting.

Knez, I. (2001). Effects of colour of light on nonvisual psychological processes. Journal of Environmental Psychology, 21, 201-208.

AIM: This study investigated the influence of color of light on subjects' self-reported mood, cognitive performance and room light estimation. METHOD: 108 subjects were randomly assigned to one of three lighting conditions ('warm', 'cool' and artificial 'daylight' white lighting). RESULTS: Although no direct effect on positive and negative mood was indicated, a main effect of gender on several room light estimation dimensions showed that females perceived the room light, across all light settings, as more expressive than did males. Main effects of color of light on short-term memory and problem solving showed that subjects performed better in the 'warm' than in the 'cool' and artificial 'daylight' white lighting. Interaction effects between colour of light and gender on long-term memory showed that males performed best in the 'warm' and 'cool' white lighting, and that women performed better than men in the artificial 'daylight' white lighting.

Knez, I. & Engmarker, I. (1998). Effects of office lighting on mood and cognitive performance and a gender effect in work-related judgment. Environment and Behavior, 4, 580-594.

AIM: To investigate the effects of the recommended office lighting on mood and cognitive performance METHOD: Subjects performed a cognitively demanding appraisal task under conditions of reddish and bluish lighting. A gender effect in task performance was examined, both as a between- and within-subject factor. RESULTS: The results showed no significant effect of the lighting on the performance of cognitive tasks. However, an interaction between gender and color temperature on mood showed that 3000K (more reddish) and 4000K (more bluish) office lighting may communicate different affective loadings or meanings to each gender. The cognitive workload induced by almost 2 hrs of intellectual work diminished positive mood and augmented a negative mood. Moreover, independently of their gender, the raters evaluated the neutral female significantly different from the neutral male ratee.

Knez, I., & Kers, C. (2000). Effects of indoor lighting, gender, and age on mood and cognitive performance. Environment and Behavior, 6, 817-831.

AIM: To examine the impact of indoor lighting, gender, and age on mood and cognitive performance. METHOD: A between subjects experiment. RESULTS: A 2-way interaction between type of lamp and age on negative mood showed that younger adults (about 23 yrs old) best preserved a negative mood in the "warm" (more reddish) white lighting while working with a battery of cognitive tasks for 90 min; for the older adults (about 65 yrs old), "cool" (more bluish) white lighting accounted for the identical effect. The younger females were shown to preserve the positive mood as well as the negative mood better than the younger males, and a main effect of age in all cognitive tasks revealed the superiority of younger to older adults in cognitive performance.

Küller, T., & Laike, R. (1998). The impact of flicker from fluorescent lighting on well-being, performance and physiological arousal. Ergonomics, 41, 433-447.

AIM: To study the impact of the non-visible flicker from fluorescent tubes on well-being, performance and physiological arousal. METHOD: 37 healthy males and females were subjected to fluorescent light powered by conventional and high-frequency ballasts condition in a laboratory office on two separate occasions with 1 week in between. RESULTS: When the light was powered by the conventional ballasts, individuals with high critical flicker fusion frequency (CFF) responded with a pronounced attenuation of EEG alpha waves, and an increase in speed and decrease in accuracy of performance. These results may be understood in terms of heightened arousal in the central nervous system in response to the pronounced light modulation caused by the conventional ballasts.

Küller, R. & Wetterberg, L. (1993). Melatonin, cortisol, EEG, ECG and subjective comfort in healthy humans: Impact of two fluorescent lamp types at two light intensities. Lighting Research and Technology, 25 (2) 71-81.

AIM: To investigate the impact of fluorescent light on endocrine, neurophysiological, and subjective indices of well being and stress. METHOD: Impacts of two types of fluorescent lamps, 'daylight' and 'warm-white', were compared, each at two different levels of illuminance. Exposure lasted one day for each of the four combinations. RESULTS: The condition involving daylight lamps with a high illuminance evoked a negative response pattern. The social evaluation of the office space went down, and at the same time the visual discomfort increased. The EEG contained less delta rhythm under the high illuminance conditions. During the day of light exposure the alpha rhythm became attenuated under the 1700 lux daylight lamps. CONCLUSION: The results warrant the conclusion that fluorescent light of high illuminance may arouse the central nervous system and that this arousal will become accentuated if the lamps are of the 'daylight' type.

Veitch, J.A. (1997). Revisiting the performance and mood effects of information about lighting and fluorescent lamp type. Journal of Environmental Psychology, 17, 253-262.

AIM: To study the effects of information sets about full-spectrum lighting on performance and mood.METHOD: In a 2 (lamp type) × 4 (information sets) × 2 (gender) factorial experiment, 104 male and 104 female participants were led to expect good, poor or indifferent outcomes of working under full-spectrum or cool-white fluorescent lighting, or they were not given any information. RESULTS: There were no effects of lamp type or information set on performance or mood.

Veitch, J. A., Gifford, R., & Hine, D.W. (1991). Demand characteristics and full spectrum lighting effects on performance and mood. Journal of Environmental Psychology, 11, 87-95.

AIM: To test the hypothesis that demand characteristics, not lamp type *per se*, underlie the anecdotal reports of beneficial effects of full spectrum lighting on performance and mood. METHOD: 86 subjects worked under either full spectrum or cool white fluorescent lamps. Under full spectrum lamps they were given one of three instruction sets: 'Full spectrum lamps improve performance and decrease fatigue' (positive set); 'There is no evidence to support such claims' (negative set); or neutral information about light. The participants in the cool white condition received only the neutral information set. RESULTS: When existing beliefs about lighting are controlled, both positive and negative information about full spectrum lighting effects lead to improved reading performance and increased self-reported arousal. No effect of lamp type was found.

Walch, J.M., Rabin, B.S., Day, R., Williams, J.N., Choi, K., & Kang, J.D. (2005). The effect of sunlight on post-operative analgesic medication usage: A prospective study of spinal surgery patients. Psychosomatic Medicine, 67(1), 156-163

AIM: To evaluate whether the amount of sunlight in a hospital room affects a patient's psychosocial health, the quantity of analgesic medication used, and the pain medication cost. METHOD: A prospective study of pain medication use was conducted in 89 patients undergoing elective cervical and lumbar spinal surgery where they were housed on either the bright or dim side of the same hospital unit. Analgesic medication was converted to standard morphine equivalents for interpatient comparison. The intensity of sunlight in each hospital room was measured daily and psychologic questionnaires were administered on the day after surgery and at discharge. RESULTS: Patients staying on the bright side of the hospital unit were exposed to 46% higher-intensity sunlight on average. Patients exposed to an increased intensity of sunlight experienced less perceived stress, marginally less pain, took 22% less analgesic medication per hour, and had 21% less pain medication costs. Age also affected medication use, but patients housed on the bright side of the hospital consistently used less analgesic medications in all age groups. COMMENT: Amount of sunlight was confounded with the content of the view.

Wilkins, A.J., Nimmo-Smith, I., Sater, A.J., & Bedocs, L., (1989, Study 1 & 2). Fluorescent lighting, headaches and eyestrain. Lighting Research and Technology, 21, 11-18.

AIM: To study the effect of daylight and different types of fluorescent lighting on headaches and eyestrain. METHOD: In a double-blind cross-over design, the weekly incidence of headaches among office workers was compared when the offices were lit by fluorescent lighting. Incidence of headaches was also related to amount of daylight coming from a light well. RESULTS: The average incidence of headaches and eyestrain was more than halved under high-frequency lighting. The incidence was unaffected by the speed with which the tubes ignited. Headaches tended to decrease with the height of the office above the ground and thus with increasing natural light from a light well. Office occupants chose to switch on the high-frequency lighting for 30% longer on average.

Wirz-Justice A, Graw P, Krauchi K, Sarrafzadeh A, English J, Arendt J, Sand L. (1996). 'Natural' light treatment of seasonal affective disorder. Journal of Affective Disorders, 37(2-3), 109-20.

AIM: To investigate the effects of exposure to natural light on seasonal affective disorder. METHOD: Patients with seasonal affective disorder were treated for 1 week either with a daily 1-h morning walk outdoors (natural light) or low-dose artificial light. The latter treatment (given under double-blind conditions) can be considered mainly placebo. RESULTS: Artifical (placebo) light did not improve any of the depression self-ratings, whereas natural light exposure improved all self-ratings. According to the Hamilton depression score, 25% remitted after low-dose artificial light and 50% after the walk. Sleep duration or timing were not crucial for the therapeutic response. The morning walk phase-advanced the onset and/or offset of salivary melatonin secretion, but individual clinical improvement could not be correlated with specific phase-shifts. Morning cortisol was decreased. Low-dose artificial light did not modify melatonin or cortisol patterns.

Fresh air

Apte, M.G., Fisk, W.J. and Daisey, J.M. (2000) Associations between indoor CO2 concentrations and sick building syn-drome symptoms in US office buildings: an analysis of the 1994-1996 BASE study data, Indoor Air, 10, 246-257.

AIM: To assess the relationship between indoor CO2 concentrations and SBS symptoms in office buildings. METHOD: The relationship between indoor CO2 concentrations and self-reported SBS symptoms in 1579 occupants of 41 U.S. office buildings was estimated using multivariate logistic regression (MLR) analyses. Two CO2 indexes were constructed: average workday indoor minus average outdoor CO2 (dCO2) and maximum indoor 1-h moving average CO2 minus outdoor CO2 concentrations (dCO2MAX). RESULTS: A dose-response relationship between ventilation and sore throat, nose/sinus, tight chest, wheezing was observed for both CO2 measures. COMMENT: Ventilation rate was not actually measured in this study.

Brundage, J.F., Scott, R.M., Lednar, W.M., Smith, D.W. & Miller, R.N. (1988) Building-associated risk of febrile acute respiratory diseases in Army trainees. Journal of the American Medical Association, 259, 2108- 2112.

AIM: To study whether energy conservation measures that tighten buildings are associated with increased risks of respiratory infection among building occupants. METHOD: At four army training centers during a 47-month period, incidence rates of febrile acute respiratory disease were compared between basic trainees in modern (energy-efficient design and construction) and old barracks. RESULTS: Rates of febrile acute respiratory disease were significantly higher among trainees in modern, and relative risks were consistent at the four centers. CONCLUSION: These results support the hypothesis that tight buildings with closed ventilation systems significantly increase risks of respiratory-transmitted infection among susceptible occupants.

Burge, S., Hedge, A., Wilson, E., Bass, J.H. & Robertson, A. (1987). Sick Building syndrome: a study of 4373 office workers. Annals of Occupational Hygiene, 31, 493-504.

AIM: To study SBS symptoms in buildings with different types of ventilation systems. METHOD: Self-reported SBS symptoms of 4373 office workers were compared between buildings with natural ventilation (11), mechanical ventilation (7) and air-conditioning (24). RESULTS: It was found that prevalence of self-reported symptoms such as nasal congestion, dry throat, and headache, was less in naturally and mechanically ventilated buildings.

Drinka, P.J., Krause, P., Schilling, M., Miller, B.A., Shult, P. and Gravenstein, S.(1996) Report of an outbreak: nursing home architecture and influenza-A attack rates, Journal of the American Geriatric Society, 44, 910- 913.

AIM: To determine factors that might account for a significantly lower attack rate in a newly constructed nursing building during an epidemic of type A influenza. METHOD: Prospective surveillance with retrospective analysis was used to assess the attack rate of influenza A in a four-building, long-term care facility for veterans and their spouses, with an average daily census of 690. RESULTS: An influenza A (H3N2) outbreak was culture-confirmed in

68 nursing home residents. Building A had significantly fewer culture-confirmed cases than the other buildings. Building A had a unique ventilation system, more square feet of public space per resident, and does not contain office space that serves the entire four-building facility. CONCLUSION: Architectural design may influence the attack rate of influenza A in nursing homes.

Everett W.D. & Kipp, H. (1991). Epidemiologic observations of operating room infections resulting from variations in ventilation and temperature. American Journal of Infection Control, 19(6):277-82.

AIM: To study the influence of increased ventilation rate on infection rates. METHOD: Wound infection rates of 1998 patients in a publicly funded military facility were measured before, during and after installment of an improved air-conditioned ventilation system in three operating rooms. RESULTS: Increasing the ventilation rate during summer months decreased infection rate. CONCLUSION: Increased ventilation rate can protect against infections in summer.

Fisk, W.J., Mendell, M.J., Daisey, J.M., Faulkner, D., Hodgson, A.T., Nematollahi, M. & Macher, J.M. (1993). Phase 1 of the California healthy building study. Indoor Air, 4, 246-254.

AIM: To compare the risk of SBS symptoms in buildings with different types of ventilation systems. METHOD: Logistic regression models were used to evaluate associations between self-reported SBS symptoms of 880 occupants of twelve public office buildings and features of the buildings, indoor environments, jobs, and personal factors. Three buildings were naturally ventilated, three were mechanically ventilated, and six were air conditioned. RESULTS: The occupants of the mechanically ventilated and air conditioned buildings had significantly more symptoms than occupants of the naturally ventilated buildings after adjustment for confounding factors. COMMENT: Ventilation type was confounded with opening of windows and building age.

Hoge, C.W., Reichler, M.R., Dominguez, E.A., Bremer, J.C., Mastro, T.D., Hendricks, K.A., Musher, D.M., Elliott, J.A., Facklam, R.R. & Breiman, R.F. (1994). An epidemic of pneumococcal disease in an overcrowded, inadequately ventilated jail. New England Journal of Medicine, 331, 643-648.

AIM: To investigate an outbreak of pneumococcal disease that was identified in an overcrowded Houston jail. METHOD: Risk factors for pneumococcal disease in both a case-control and a cohort study were assessed. Ventilation was evaluated by measuring carbon dioxide levels and air flow to the living areas of the jail. The extent of asymptomatic infection was determined by culturing pharyngeal specimens from a random sample of inmates. Type-specific immunity was determined with an enzyme immunoassay. RESULTS. Over a four-week period, 46 inmates had either acute pneumonia or invasive pneumococcal disease due to Streptococcus pneumoniae serotype 12F. The attack rate was highest among inmates in cells with the highest carbon dioxide levels and the lowest volume of outside air delivered by the ventilation system . Of underlying medical conditions, intravenous drug use was most strongly associated with disease. Of 11 case patients tested with the enzyme immunoassay, 9 (82 percent) lacked preexisting immunity to this strain. CONCLUSIONS. Severe overcrowding, inadequate ventilation, and altered host susceptibility all contributed to an outbreak of pneumococcal disease in a large urban jail.

Jaakkola, J.J.K., Heinoneon, O.P, & Seppanen, O. (1991). Mechanical ventilation in office buildings and the Sick Building Syndrome. An experimental and epidemiological study. Indoor Air, 1, 111 – 121.

EXPERIMENTAL STUDY: AIM: To study the effects of ventilation rate on the sick building syndrome (SBS). METHOD: A controlled experimental study was carried out in an office building with 2150 employees who frequently complained about the mechanical ventilation system. The ventilation was shut off in one part of the building and reduced by 75% and 60% in two areas while leaving one part unaltered as a control. RESULTS: The experimental reduction of the ventilation rate did not alleviate the symptoms. On the contrary, the reduction of the ventilation rate caused a slight but statistically significant relative increase in symptoms.

EPIDEMIOLOGICAL STUDY: A cross-sectional analysis of the baseline data revealed that SBS symptoms did not associate significantly with the ventilation rate (range 7-70 l/s/person). Temperature, gender, tobacco smoke, a prior history of allergic diseases, a negative attitude towards the social atmosphere at work were significant determinants of SBS symptoms.

Jaakkola, J.J. & Miettinen, P. (1995a) Ventilation rate in office buildings and sick building syndrome. Occupational and Environmental Medicine, 52, 709-714.

AIM: To examine the relation between ventilation rate and SBS symptoms. METHOD: A cross sectional population based study was carried out among 399 workers from 14 mechanically ventilated office buildings without air recirculation or humidification in the Helsinki metropolitan area. The ventilation type and other characteristics of these buildings were recorded on a site visit and the ventilation in the rooms was assessed by measuring the airflow through the exhaust air outlets in the room. A questionnaire directed at workers inquired about the symptoms and perceived air quality and their possible personal and environmental determinants (response rate 81%). RESULTS: Logistic regression analysis showed that risk of symptoms was higher in offices with low ventilation rates (below 5 l/s per person) than in offices with high ventilation rates (over 25 l/s per person). The risks for ocular, nasal, skin and lethargy increased significantly by a unit decrease in ventilation from 25 to 0 l/s per person. CONCLUSION: The results suggest that outdoor air ventilation rates below the optimal (15 to 25 l/s per person) increase the risk of SBS symptoms in mechanically ventilated office buildings.

Jaakkola, J.J. & Miettinen, P. (1995b) Type of ventilation system in office buildings and sick building syndrome. American Journal of Epidemiology, 141, 755-765.

AIM: To examine the role of ventilation type in office buildings as a determinant of self-reported symptoms of Sick Building Syndrome. METHOD: A cross-sectional study was carried out among 2,678 workers from 41 office buildings selected randomly from the Helsinki metropolitan area. RESULTS: In logistic regression analysis adjusting for potential confounders, simple mechanical ventilation (mechanical supply and exhaust ducts) was related to a higher risk of ocular symptoms, nasal congestion and discharge, pharyngeal symptoms, and lethargy compared with natural ventilation. Air conditioning was related to a slightly higher risk of symptoms compared with simple mechanical ventilation. There was no increased risk of SBS symptoms in air-conditioned building with humidification.

Loo, V.G., Bertrand, C., Dixon, C., Vitye, D., DeSalis, B., McLean, A.P., et al. (1996). Control of construction-associated nosocomial aspergillosis in an antiquated hematology unit. Infection Control and Hospital Epidemiology, 17(6), 360-364.

AIM: To determine the effect of an environmental control program on the incidence of aspergillosis in patients with leukemia or bone marrow transplants during a construction-associated outbreak. DESIGN: Clinical, microbiological, and pathological records of 141 patients with leukemia or bone marrow transplants in a university tertiary-care center were reviewed before and after an outbreak of aspergilosis to determine the presence or absence of aspergillosis and duration of neutropenia. After the outbreak, wall-mounted portable high-efficiency particulate air (HEPA)-filter air purifiers were installed, along with the application of copper-8-quinolinolate-formulated paint, replacement of perforated ceiling tiles with nonperforated type, sealing of all windows, replacement of horizontal, dust-accumulating blinds with vinyl, opaque, roller shades, and systematic and regular cleaning of surfaces. RESULTS: Thirty-six cases of nosocomial aspergillosis were diagnosed during this period. The incidence density (ID) in the preconstruction period was 3.18 per 1,000 days at risk. During construction activity-before the implementation of a control strategy-the ID increased dramatically to 9.88 per 1,000 days at risk. With infection control measures implemented and continued construction work, the ID decreased to 2.91 per 1,000 days at risk, comparable to the preconstruction baseline rate. CONCLUSION: The environmental control strategy may have played an important role in controlling this outbreak of construction-associated invasive aspergillosis.

Mendell, M.J., Fisk, W.J., Deddens, J.A., Seavey, W.G., Smith, A.H., Smith, D.F., Hodgson, A.T., Daisey, J.M. & Goldman, L.R. (1996). Elevated symptom prevalence associated with ventilation type in office buildings. Epidemiology, 7, 583- 589.

AIM: To assess relations between ventilation system type and office worker symptoms in a set of U.S. buildings. METHOD: Twelve public office buildings in northern California meeting specific eligibility criteria were studied in the summer of 1990: three naturally ventilated, three mechanically ventilated (without air conditioning), and six air-conditioned buildings. Questionnaire data were collected from 880 workers in selected spaces within the study buildings. Effect estimates for various ventilation types were adjusted for personal, job, and work place factors using logistic regression, and alternatively, using a mixed effects model to adjust for correlated responses within study spaces. RESULTS: Higher adjusted prevalences of most symptom outcomes were associated with both mechanical and air-conditioned ventilation, relative to natural. With a conservative adjustment for problem building status, the highest adjusted prevalence odds ratios from logistic regression models were for dry or itchy skin and lower respiratory symptoms.

Menzies, R., Tamblyn, R.M., Farant, J-P, Hanley, J., Nunes, F., Tamblyn R.T. (1993). The effect of varying levels of outdoor-air supply on the symptoms of sick building syndrome. New England Journal of Medicine, 328, 821-827.

AIM: To determine the effect of changing the supply of outdoor air in office buildings on self-reported SBS symptoms. METHOD: Within each of three consecutive two-week blocks, the ventilation systems in four building were manipulated, in random order, to deliver to the indoor environment an intended 20 or 50 ft^3 (0.57 or 1.4 m^3)

of outdoor air per minute per person for one week at a time. Each week, 1546 workers, who were unaware of the experimental intervention, reported symptoms and the indoor environment was thoroughly evaluated. RESULTS: Changes in the supply of outdoor air were not associated with changes in the participants' ratings of the office environment or in symptom. CONCLUSION: Increases in the supply of outdoor air did not appear to affect workers' perceptions of their office environment or their reporting of symptoms considered typical of the sick building syndrome.

Milton, D., Glencross, P. & Walters, M. (2000). Risk of sick-leave associated with outdoor air supply rate, humidification and occupants complaints. Indoor Air, 10, 212-221.

AIM: To study the relationship between outdoor supply rate and risk of sick leave. METHOD: 1994 sick leave for 3,720 hourly employees of a large Massachusetts manufacturer in 40 buildings with 115 independently ventilated work areas were analyzed. Corporate records identified building characteristics and IEQ complaints. Ventilation of outdoor air was rated as moderate or high based on knowledge of ventilation systems and CO2 measurements on a subset of work areas. Poisson regression was used to analyze sick leave controlled for age, gender, seniority, hours of non-illness absence, shift, ethnicity, crowding, and type of job (office, technical, or manufacturing worker). RESULTS: Increased sick leave was found to be consistently associated with lower levels of outdoor air supply. The effect of ventilation was independent of IEQ complaints and among those exposed to lower outdoor air supply rates the attributable risk of short-term sick leave was 35%. The cost of sick leave attributable to ventilation at current recommended rates was estimated as $480 per employee per year. CONCLUSION: These findings suggest that net savings of $400 per employee per year may be obtained with increased ventilation.

Myatt, T.A., Staudenmayer, J., Adams, K., Walters, M., Rudnick, S.N., & Milton, D.K. (2002) A study of indoor carbon dioxide levels and sick leave among office workers. Environmental Health,1(1):3.

AIM: To explore the relationship between sick leave absences and carbon dioxide (CO2) concentrations in office buildings due to a low dilution ventilation. METHOD: An intervention study of indoor CO2 levels and sick leave among hourly office workers employed by a large corporation. Outdoor air supply rates were adjusted periodically to increase the range of CO2 concentrations. Indoor CO2 concentrations were recorded every 10 minutes and a CO2 concentration differential was calculated as a measure of outdoor air supply per person by subtracting the 1-3 a.m. average CO2 concentration from the same-day 9 a.m. - 5 a.m. average concentration. The metric of CO2 differential was used as a surrogate for the concentration of exhaled breath and for potential exposure to human source airborne respiratory pathogens. RESULTS: No association was found between sick leave and CO2 differential. CONCLUSIONS: The CO2 differential was in the range of very low values, as compared with the recommended maximum differential of 700 ppm. Although no effect was found, this study was unable to test whether higher CO2 differentials may be associated with increased sick leave

Norbäck, D., Björnsson, E., Janson, C., Widström m, J., & Boman, G. (1995). Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings. Occupational and Environmental Medicine, 52, 388-395.

AIM: To study possible relations between symptoms of asthma, building characteristics, and indoor concentration of volatile organic compounds (VOCs) in dwellings. METHOD: The study comprised 88 subjects, aged 20-45 years, from the general population in the Swedish town of Uppsala, selected by stratified random sampling. Room temperature, air humidity, respirable dust, carbon dioxide (CO2), VOCs, formaldehyde, and house dust mites were measured in the homes of the subjects. They underwent a structured interview, spirometry, peak expiratory flow (PEF) measurements at home, methacholine provocation test for bronchial hyperresponsiveness, and skin prick tests. In addition, serum concentration of eosinophilic cationic protein, blood eosinophil count, and total immunoglobulin E were measured. RESULTS: Symptoms related to asthma were more common in dwellings with house dust mites, and visible signs of dampness or microbial growth in the building. Significant relations were also found between nocturnal breathlessness and presence of wall to wall carpets, and indoor concentration of CO2, formaldehyde, and VOCs. CO2 exceeded the recommended limit value of 1000 ppm in 26% of the dwellings, showing insufficient outdoor air supply. CONCLUSION: The results suggest that indoor VOCs and formaldehyde may cause asthma-like symptoms. There is a need to increase the outdoor air supply in many dwelling, and wall to wall carpeting and dampness in the building should be avoided.

Øie, L., Nafstad, P., Botten, G., Magnus, P. & Jaakkola, J.K. (1999). Ventilation in homes and bronchial obstruction in young children. Epidemiology, 10, 294- 299.

AIM: To assess the role of ventilation rate in homes in the development of bronchial obstruction during the first 2 years of life. METHOD: A matched case-control study based on a cohort of 3,754 newborns in Oslo in 1992-93 that was followed for 2 years. The case series comprised 172 children with bronchial obstruction, and the control series was one-to-one matched for date of birth. Ventilation rate and other building characteristics were measured/ collected in home visits, and questionnaires were used to obtain additional information. RESULTS: Risk of bronchial obstruction was not directly associated with the ventilation rate in liters per second and per person in the homes. The odds ratios of bronchial obstruction were higher in the low air change than in the high air change group owing to exposure to environmental tobacco smoke, dampness problems, and the presence of textile wall paper, and plasticizer-containing surfaces. CONCLUSION: The results are consistent with the hypothesis that low ventilation rates strengthen the effects of indoor air pollutants.

Asp, A.S.M., A.A., Cannady, P.B., Jr., Morse, P.L., Burton, L.J., & Hammer, P.G. (1986). Efficacy of infection control measures during a nosocomial outbreak of disseminated aspergillosis associated with hospital construction. Journal of Infectious Diseases, 153(3), 634-637.

AIM: To study the efficacy of control measures to reduce the risk of infections among patients hospitalized in institutions undergoing construction. METHOD: A HEPA filter was installed during the outbreak of an Aspergillosis infection. RESULTS: The outbreak was terminated, despite the continuation of major renovation projects in close proximity to patient care areas. The total number of hospital discharges, patients with lymphoreticular malignancies, and patients receiving chemotherapy did not change significantly during the five-year study period.

Oren, I., Haddad, N., Finkelstein, R., & Rowe, J.M. (2001). Invasive pulmonary aspergillosis in neutropenic patients during hospital construction: Before and after chemoprophylaxis and institution of HEPA filters. American Journal of Hematology, 66(4), 257-262.

AIM: To study the effectiveness of chemoprophylaxis and institution of HEPA filters to control a nosocomial outbreak of invasive pulmonary aspergillosis in acute leukemia patients treated in a regular ward that has only natural ventilation. METHOD: Chemoprophylaxis with intravenous continuous low-dose amphotericin B was instituted as a preventive measure after the outbreak of invasive pulmonary aspergillosis. After 18 months a new hematology ward was opened with an air filtration system through HEPA filters, and a bone marrow transplantation program was started on the hematology service. RESULTS: During the 18 months after chemoprophylaxis invasive pulmonary aspergillosis developed in 43% of acute leukemia patients. During the three years after installment of the HEPA filters, none of the acute leukemia or bone marrow transplantation patients who were hospitalized exclusively in the hematology ward developed invasive pulmonary aspergillosis, although 29% of acute leukemia patients who were housed in a regular ward, because of shortage of space in the new facility, still contracted invasive pulmonary aspergillosis. Overall, 31 patients were diagnosed with invasive pulmonary aspergillosis during almost five years: 74% of patients recovered from invasive pulmonary aspergillosis, and 42% are long-term survivors; 26% of patients died of resistant leukemia with aspergillosis, but no one died of invasive pulmonary aspergillosis alone. CONCLUSION: During an on-going construction period, an extremely high incidence rate of invasive pulmonary aspergillosis in acute leukemia patients undergoing intensive chemotherapy was observed. Institution of low-dose intravenous amphotericin B prophylaxis marginally reduced the incidence rate of invasive pulmonary aspergillosis. Keeping patients in a special ward with air filtration through a HEPA system eliminated invasive pulmonary aspergillosis completely.

Skov, P. & Valbjørn, O. (1987). The sick building syndrome in the office environment: The Danish Town Hall study. Environment International, 13, 339-349.

AIM: To study relationships between indoor climate factors and SBS symptoms in offices. METHOD: Measurements of the indoor climate were performed in 14 town halls in Greater Copenhagen, Denmark, together with a questionnaire study and a clinical study of 4369 employees in the town halls and 14 affiliated buildings. The return rate for the questionnaire study was 80% and the participation rate for the clinical study 77%. RESULTS: The prevalence of work-related mucosal irritation and of work-related general symptoms in the employees differed highly between the individual town halls. The lowest prevalences of symptoms were found for the oldest town halls, whereas there were no statistically significant differences between naturally and mechanically ventilated buildings. Gender, job category, photoprinting, working with video display terminals, and handling carbonless paper correlated significantly with the presence of work-related mucosal irritation and general symptoms.

Smedje, G. & Norbäck, D. (2000) New ventilation systems at select schools in Sweden - effects on asthma and exposure. Archives of Environmental Health, 55, 18-25.

AIM: To study the possible impact of improving school ventilation on health and exposure of pupils. METHOD: Questionnaire data on allergies, asthma, and asthmatic symptoms were obtained in 1993 and 1995 for 1,476 primary- and secondary-school pupils in 39 randomly selected schools. Various exposure factors were measured in 1993 and 1995 in approximately 100 classrooms. In 12% of the classrooms, new ventilation systems were installed between 1993 and 1995. RESULTS: After the installment of new ventilation systems, the air-exchange rate increased and the relative humidity and concentration of several airborne pollutants were reduced compared with classrooms in nonimproved buildings. The reporting of at least one asthmatic symptom and the reporting of more asthmatic symptoms in 1995 than in 1993 were less common among the 143 pupils who attended schools with new ventilation systems.

Sundell, J., Lindvall, T., & Stenberg, B. (1994). Associations between type of ventilation and air flow rates in office buildings and the risk of SBS-symptoms among occupants. Environment International, 20, 239- 251.

AIM: To study the association between type of ventilation and outdoor-air flow rates and SBS symptoms. METHOD: A cross-sectional questionnaire and field study comprising 160 office buildings, and 260-2649 respondents with case-controls as well as prevalence comparisons. RESULTS: Measured ventilation rates were higher than required by most building codes. Increased risk of SBS and elevated prevalence of general SBS symptoms were associated with low outdoor-air flow rates, presence of copying machines in office rooms, and ventilation operating hours less than 10 h/d.

Wälinder, R., Norbäck, D., Wieslander, G., Smedje, G., Erwall, C. & Venge, P. (1998). Nasal patency and biomarkers in nasal lavage - the significance of air exchange rate and type of ventilation in schools. International Archives of Occupational and Environmental Health, 71, 479-486.

AIM: To examine the relationships between the ventilation rate and type of ventilation system and objective nasal measures. METHOD: A standardized investigation, including acoustic rhinometry and nasal lavage, was performed in the school environment. 234 (84%) of 279 school personnel working 12 randomly selected primary schools participated in the study. The dimensions of the nasal cavity were measured with acoustic rhinometry. Eosinophil cationic protein (ECP), myeloperoxidase (MPO), lysozyme, and albumin were analyzed in the lavage fluid. The air exchange rate and the room temperature were measured in the classrooms. Relationships between nasal measures and the type of ventilation system were controlled for the type of ventilation, the air exchange rate, room temperature, age, gender, smoking, atopy, and the urban vicinity of the school. RESULTS: A lower degree of nasal patency as measured by acoustic rhinometry and increased levels of ECP and lysozyme in nasal lavage were associated with a lower air exchange rate in the schools. Although mechanically ventilated schools had higher air exchange rates, they were associated with more nasal symptoms, and nasal mucosal swelling and with increased lavage levels of ECP and lysozyme as compared with schools with natural ventilation only. In contrast, 12 subjects working in a school with mechanical displacement ventilation had more patent noses and lower levels of inflammatory markers as compared with the personnel in schools with natural ventilation only. CONCLUSION: The results indicate that both a low air exchange rate and mechanical ventilation systems based on dilution can be associated with reduced nasal patency and an inflammatory biomarker response of the nasal mucosa among school personnel.

Wargocki P, Wyon D.P., Fanger P.O. (2004). The performance and subjective responses of call-center operators with new and used supply air filters at two outdoor air supply rates. Indoor Air, 14 Suppl 8, 7-16.

AIM: To study the performance and responses of call-center operators with new and used supply air filters at different outdoor air supply rates. METHOD: A 2 x 2 replicated field intervention experiment was conducted in a call-center providing a telephone directory service: outdoor air supply rate was adjusted to be 8% or 80% of the total airflow and the supply air filters were either new or had been in place for 6 months. One of these independent variables was changed each week for 8 weeks. The interventions did not affect room temperature, relative humidity or noise level. The 26 operators were blind to conditions and each week returned questionnaires recording their environmental perceptions SBS symptoms. Their performance was continuously monitored by recording the average talk-time every 30 min. RESULTS: Replacing a used filter with a clean filter reduced talk-time by about 10% at the high ventilation rate but had no significant effect at the low rate. Increasing the outdoor air supply rate reduced talk-time by 6% with a new filter in place but increased talk-time by 8% with a used filter in place. The interventions also had significant effects on some SBS symptoms and environmental perceptions. The present results indicate that increasing outdoor air supply rate and replacing filters can have positive effects on health, comfort and performance. CONCLUSION: Increasing outdoor air supply rates may only be beneficial when new filters are installed.

Wargocki, P., Wyon, D.P., Sundell, J.,Clausen, G., & Fanger, P.O. (2000).The effects of outdoor air supply rate in an office on perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity. Indoor Air, 10, 222-236.

AIM: To examine health and productivity effects of outdoor air supply in an office. METHOD: Perceived air quality, SBS symptoms and productivity were studied in a normally furnished office space ventilated with an outdoor airflow of 3, 10 or 30 L/s per person. The temperature of 22 degrees C, the relative humidity of 40% and all other environmental parameters remained unchanged. Five groups of six female subjects were each exposed to the three ventilation rates, one group and one ventilation rate at a time. Each exposure lasted 4.6 h and took place in the afternoon. Subjects were unaware of the intervention and remained thermally neutral by adjusting their clothing. They assessed perceived air quality and SBS symptoms at intervals, and performed simulated normal office work. RESULTS: Increasing ventilation decreased the percentage of subjects dissatisfied with the air quality and the intensity of odor and increased the perceived freshness of air. It also decreased the sensation of dryness of mouth and throat, eased difficulty in thinking clearly and made subjects feel generally better. The performance of four simulated office tasks improved monotonically with increasing ventilation rates, and the effect reached formal significance in the case of text-typing. For each two-fold increase in ventilation rate, performance improved on average by 1.7%. CONCLUSION: This study shows the benefits for health, comfort and productivity of ventilation at rates well above the minimum levels prescribed in existing standards and guidelines.

Warner, J.A., Frederick, J.M., Bryant, T.N., Wiech, C., Raw, G.J., Hunter, C., Stephen, F.R., McIntyre, D.A. & Warner, J.O. (2000) Mechanical ventilation and high-efficiency vacuum cleaning: a combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma. Journal of Allergy and Clinical Immunolology, Part 1, 105, 75-82.

AIM: To investigate the effect of mechanical ventilation and high-efficiency vacuuming on house dust mite (HDM) numbers and mite allergen reduction in the homes of mite-sensitive asthmatic subjects. METHODS: The homes of 40 HDM-sensitive asthmatic subjects were randomized to receive (1) mechanical ventilation and a high-efficiency vacuum cleaner (HEVC); (2) mechanical ventilation alone; (3) an HEVC alone; and (4) no intervention. Homes and patients were monitored for 12 months. Change in absolute humidity, mite numbers, Der p 1 concentrations, lung function, bronchial hyperresponsiveness, and symptom scores were analyzed. RESULTS: Homes with mechanical ventilation achieved significantly lower humidity levels than those without, with an associated reduction of mite numbers and Der p 1 concentrations in bedroom carpets and some other mite sources in the ventilated areas of the homes. The addition of a vacuum cleaner enhanced this effect. There was a trend for an improvement in histamine in the patients whose homes were ventilated. CONCLUSION: The use of a mechanical ventilation system in suitable homes resulted in some reduction in numbers of HDM and Der p 1 concentrations. The addition of an HEVC slightly enhanced the effect but not sufficiently to see an improvement in symptoms

Zweers, T., Preller, L., Brunekreef, B., & Boleij, J.S.M. (1992). Health and Indoor Climate Complaints of 7043 office Workers in 61 Buildings in the Netherlands. Indoor Air, 2, 127-136.

AIM: To investigate the relationships between the prevalence of work-related health and indoor climate complaints. METHOD: Information on health, indoor climate complaints and personal and workplace characteristics was assessed using a questionnaire. A checklist was used to obtain information on building characteristics More than 7000 questionnaires were completed by the regular users of 60 buildings. RESULTS: The prevalence of symptoms was higher in air-conditioned buildings than in naturally or mechanically ventilated buildings. Some other variables were also related with most work-related complaints after adjustment for selected management, personal, workplace and job characteristics. These included gender, work satisfaction in general, presence of allergies and/or respiratory symptoms, and personal control over temperature at the workplace. No differences were found in symptom prevalences between buildings with spray and steam humidification. The combination of air-conditioning and humidification did not lead to further increases in the prevalence of complaints as compared to buildings with only airconditioning or only humidification.

Quiet

Berg, S. (2001). Impact of reduced reverberation time on sound-induced arousals during sleep. Sleep, 24 (3), 289-292.

AIM: To study the effect of sound-absorbing tiles on sound-induced arousals during sleep. METHOD: EEG-arousals following specific sound stimuli were studied in 12 subjects during sleep RESULTS: EEG-arousals were significantly reduced when reverberation time was reduced with sound-absorbing ceiling-tiles. On average reverberation was reduced 0.124 seconds at similar sound levels. CONCLUSION: Increased sound absorption, i.e. reduced reverberation time, may reduce sound-induced sleep fragmentation by contributing to a better acoustic environment.

Hagerman, I., Rasmanis, G., Blomkvist, V., Ulrich, R., Anne Eriksen, C., Theorell, T. (2005). Influence of intensive coronary care acoustics on the quality of care and physiological state of patients. International Journal of Cardiology, 98(2), 267-70.

AIM: To evaluate the role of room acoustics on patients with coronary artery disease. METHOD: A total of 94 patients admitted to an intensive coronary heart unit for evaluation of chest pain were included in the study. Acoustics were altered during the study period by changing the ceiling tiles throughout the CCU from sound-reflecting tiles (bad acoustics) to sound-absorbing tiles (good acoustics) of similar appearance. Patients were monitored with regard to blood pressure including pulse amplitude, heart rate and heart rate variability. The patients were asked to fill in a questionnaire about the quality of the care, and a follow-up of rehospitalization and mortality was made at 1 and 3 months, respectively. RESULTS: There were significant differences between good and bad acoustics with regard to pulse amplitude in the acute myocardial infarction and unstable angina pectoris groups, with lower values during the good acoustics period during the night. The incidence of rehospitalization was higher for the bad acoustics group. Patients treated during the good acoustics period considered the staff attitude to be much better than during the bad acoustics period. CONCLUSION: A bad acoustics environment during acute illness may have important detrimental physiological effects on rehabilitation.

Ohrstrom, E., Bjorkman, M. (1983). Sleep disturbance before and after traffic noise attenuation in an apartment building. Journal of the Acoustical Society of America, 73(3), 877-9.

AIM: To study the effects of installing noise insulating windows on sleep disturbance from traffic noise. METHOD: Three tenants completed a questionnaire each morning one week before and one week after the insulation of windows, and body movements during sleep were recorded during these periods. RESULTS: All three participants demonstrated a decrease in the number of body movements after the windows had been insulated and two reported improved sleep quality. CONCLUSION: These results suggest that subjectively judged sleep quality as well as recordings of bed movements are useful tools for evaluating actions to reduce noise.

Annex B. The Architecture of Hospitals

In 1997 the University Hospital Groningen officially opened its new building. More than a decade of reconstruction work preceded the festivities, some of the best hospital architects had worked on this project for almost thirty years. One of The Netherlands' largest hospitals, the new building radiates a pleasant, semi-urban atmosphere, a major achievement in a building this size. Two covered streets give access to the outward patient departments, each of which has been individually designed. Numerous shops, a supermarket, and a travel agency line the street that combine the two major lanes and the large hall with the building's main entrance. Designing these (semi-) public spaces has been the work of Wytze Patijn, the actual hospital was created according to the plans by Kruisheer and Team 4 (Kleinjan).

The new building of what is now known as the University Medical Center Groningen (UMCG) demonstrates that the Board of Directors believe that architecture really matters. This belief also triggered the project 'The Architecture of Hospitals'. The aim of this project is to bring the architecture of hospitals back in the center of the architectural debate. It wants to convince architects of the great artistic and cultural tradition of the hospital as a work of architecture, and healthcare decision makers of the immense importance of architecture as a factor contributing to the hospital's core business: promoting people's physical and mental well-being. The project has been organized by the 'Foundation 200 years University Hospital Groningen'.

The project The Architecture of Hospitals consists of a series of conferences, publications, and other initiatives related to hospital architecture and evidence-based design. The main activity is a major international conference on the architecture of hospitals, to be held April 13-15, 2005 in Groningen, which is supported by several symposia, preliminary conferences, and workshops. The first symposium entitled "Buildings as ideas: the hospital" was held in August 2003 in Groningen and organized by the K.L. Poll Foundation for Education, Art and Science. This symposium resulted in two products: the reader "The Hospital" (K.L. Poll Foundation, 2003), and a video called "The town in the town". Two preliminary conferences held in Groningen, November 2003 and Delft, April 2004, focused on evidence-based design and recent trends in the architecture of hospitals as healing environments. A third preliminary took the form of a one-week design workshop on the ultimate future interior of hospitals with participants from several Dutch academies. The results of this design workshop will be presented at the main conference in April, 2005, and will be exhibited in the city of Groningen for several weeks after the conference. The proceedings of the preliminary conferences and the main conference will be published in the course of 2005.

Further publications of the project include a book on the planning and building of the new University Hospital Groningen (Van den Noort, 1999), a book on Dutch hospital architecture after the Second World War (Mens & Tijhuis, 1999), a book on Dutch psychiatric clinics (Mens, 2003), and the current publication on health impacts of healing environments. In addition, a book is currently being prepared that analyzes the evolution of housing and (semi-) medical facilities for the elderly.

A final product of the project The Architecture of Hospitals is a television documentary on the role of the architect as a therapist, directed by Joost van Krieken (date of broadcast on Dutch television: April 10, 2005).

The project The Architecture of Hospitals is made possible by:

- HGIS - Netherlands Culture Fund
- Plants for People
- Stimuleringsfonds voor Architectuur - The Netherlands Architecture Fund
- Siemens
- Bam & Trebbe - construction Partnership Nelissen Van Egteren/Trebbe
- Brocacef
- ISIT - The Storage Company
- Premsela-regeling - The Netherlands Architecture Fund
- Netherlands Board for Hospital Facilities
- Deloitte
- Alterra
- PGGM
- EMC Computer Systems
- Van Heugten Consultants
- Forbo Flooring
- Bossers & Cnossen
- Getronics ICT solutions and services
- Interoffice Office Supplies
- Medtronic - Cardiac Rhythm Management
- Nashuatec copiers and printers
- Sijbes Office Supplier

The Architecture of Hospitals collaborates with:

- Amice An Amicable network of Academical Medical Centers in Europe
- University Medical Center Groningen
- BNA Royal Institute of Dutch Architects
- Health Council of the Netherlands
- NAi Netherlands Architecture Institute
- RuG University of Groningen
- STAGG Public Health Section/Royal Institute of Dutch Architects
- TU Delft - Delft University of Technology
- L’assistance publique - Hôpitaux de Paris
- Harvard University Graduate School of Design, Cambridge
- Karolinska Institute, Medical University, Stockholm
- Texas A&M University College of Architecture

Annex C. About the Author

Dr A.E. (Agnes) van den Berg is an environmental psychologist specialized in research on people's perceptions and evaluations of natural environments. In 1999, she received her Ph.D. degree for research into individual differences in preferences for wild and cultivated nature. She currently works as a senior researcher and associate professor at Wageningen University and Research Centre, The Netherlands. Her work is focused on fundamental issues in human-environment relations, including environmental preferences, health benefits of nature, fear of nature, and underlying motivational mechanisms. In addition, Agnes van den Berg is committed to the translation of theoretical insights into practical guidelines for planners, policy makers, and designers. Among the tools and instruments she has developed are a nationwide GIS-model for the monitoring and prediction of landscape beauty, and a checklist for the application of nature to the design of hospitals on behalf of the Erasmus University Medical Center, Rotterdam.

For more information about Agnes van den Berg, see her website *www.agnesvandenberg.nl*

Selected publications

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Van den Berg, A.E., Vlek, C.A.J. & Coeterier, J.F. (1998). Group differences in the aesthetic evaluation of nature development plans: A multilevel approach. *Journal of Environmental Psychology, 18*, 141-157.

Koole, S.L., & Van den Berg, A.E. (in press). Lost in the wilderness: Terror management, action control, and evaluations of nature. *Journal of Personality and Social Psychology*.

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