A Review of the Empirical Literature on the Relationships between Indoor Environment and Stress in Healthcare and Office Settings: Problems and Prospects of Sharing Evidence

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ABSTRACT

A conceptual framework linking indoor environment, user needs, and user stress is provided. The framework places environmental design research in the forefront by suggesting that, in many cases, indoor environments may set forth a process leading to stress by affecting individual and/or workplace needs. At the same time, the framework also suggests that since any direct causal relation between the physical environment and stress may be difficult to establish, environmental design research would be better served by focusing more on the evidence linking environmental design to individual and/or workplace needs.

On this basis, the review focuses primarily on the evidence that relates indoor environment to individual and/or workplace needs in healthcare and office settings. It demonstrates a growing body of literature addressing the relationship between indoor environment and individual and/or workplace needs in both settings. However the amount of currently available evidence is much greater for office settings. The review also demonstrates a general lack of evidence regarding how personal motives and attitudes, and demographic factors affect the relationship between indoor environment and user needs in these settings. Though there is some evidence regarding how individual and/or work needs may affect stress in these settings, little is stated here about the moderating effects of time and individual coping skills.

Since the available evidence on the relationships between indoor environment and individual and/or workplace needs in the research literature related to healthcare and office settings is uneven, there is a great need for the sharing of knowledge among environmental designers and researchers. In this regard, differences in organizational cultures and structures, user and workplace needs, and physical settings are some of the issues to be carefully considered.

1. INTRODUCTION

Studies show that stress may have negative effects on physiological, psychological, cognitive, behavioral, psychosocial, and social outcomes (e.g., Gatchel, Baum, & Krantz 1989; Ulrich 1991; Kiecolt-Glaser et al. 1987, 1995). The physical environment is important for it may induce stress by the ways in which it affects individual needs. A conceptual framework describing how the physical environment of a building

may affect individual stress through its effects on an individual's needs is provided in figure 1. The framework groups the physical environmental variables into two categories: indoor environmental variables and interior design variables. Indoor environmental variables include noise, lighting, ambient temperature, and air quality, while interior design variables include the use of space, furniture, fixtures and equipment, finish materials, color, artwork, natural views, and environmental graphics. In real life, interactions among some of these variables may occur, thus contributing to the process of stress. For example, depending on the use of flooring and surface materials the quality of sound in a space may either be enhanced or deteriorated. The way colors are used can either enhance or deteriorate the quality of the lighting in a space. The use of equipment for the purpose of improving air quality may become a source of noise when improperly located inside a building; and so on. The conceptual framework does not disregard these interactions, but for analytic and descriptive convenience, it treats all physical environmental variables as independent variables. Any negative environmental effects of these variables are treated as immediate outcome variables.

According to this conceptual framework, immediate outcome variables with somewhat direct associations with stress may be affected when individual needs are thwarted by some environmental features. For example, the open layout of a workplace (an interior design variable) may reduce an individual's sense of privacy (a psychosocial need); as a result, her task performance may suffer (an immediate outcome variable). However, another factor to be considered here is the relative importance of privacy to the individual. If a person considers privacy as a trivial workplace need, she may perform well even without workplace privacy. But if privacy is considered to be an important workplace need, both her performance and stress levels may be negatively affected in a workplace that does not offer individual privacy.

The process leading to stress is made even more complicated by the fact that everyone is not affected equally when deprived of the same important need/s. Physiological needs may be more important for patients in hospitals than for workers in offices. Psychosocial needs may be more important for office workers than for patients. Older people may be more affected by noise and lighting conditions than younger people. Some cognitive needs may be more pressing for highly educated individuals. An individual's response to deprived needs may also depend on motives and attitudes. For example, noise in classrooms may have a lesser impact on a highly motivated student. In sum, motives, attitudes, and demographic factors may have moderating effects on how deprivation of individual needs may affect the resulting immediate outcomes.

The ways in which a person is affected when her needs are thwarted may also depend on several organizational factors including organizational leadership and culture. Organizational leadership can be

defined as the capacity of individuals to influence others toward the organizationally relevant goals/objectives. Unit culture constitutes the norms, values, beliefs, and expectations shared by people who work in the organization. Cook, Lafferty, and Level (1987) suggest that the orientation of any organizational culture can be defined by the following three factors: (1) a team-satisfaction oriented factor, (2) a people-security orientation factor, and (3) a task-security orientation factor. It is plausible that a team-satisfaction oriented culture, which emphasizes self-expression, achievement, cooperation, and staff development, may be associated with positive individual outcomes. A people-security oriented culture, which emphasizes approval, adherence to procedures, dependence, and avoidance of conflict, may cause unnecessary workplace tensions leading to negative individual outcomes. A task-security oriented culture, which emphasizes perfectionism, competition, and authoritarian control, may put significant psychological pressures on individuals, also leading to negative outcomes.

Note that any negative effect on immediate individual outcomes does not automatically result in stress. An individual's level of stress due to any negative effect on one or more immediate outcomes may depend on her coping skills. Two individuals with the same demographic background and/or motivation level may simply react differently to the same stressors, because their coping skills and abilities are different. Coping skills can be behavioral, physiological, psychological, and cognitive in nature, and can be employed singularly or in any combination. The effectiveness of one's coping skills may depend not only on one's ability to apply the skill, but also on the context within which stress occurs. Time may be an additional factor determining the potency of environmental stressors. In some contexts, people may simply get used to a stressor if exposed to it for an extended period. In other contexts, a mild stressor may have a major effect if an individual is exposed to it for an extended period.

This conceptual framework presents the researcher with a great deal of complexity. Clearly, all the propositions made here can not always be encompassed within a single research field. Based on research fields, the focus of studies on stress may shift from one part of the framework to another. For example, from the clinical perspective, stress is primarily a psycho-physiological phenomenon that arises from an individual's perception of balance between environmental demands and response capabilities (e.g., Davidson & Cooper, 1981; French & Caplan, 1970; McGarth, 1970). As a result, most research based on this perspective focuses on individual perceptions and susceptibility, and most interventions are directed toward individual coping strategies, as described in the last segment of the framework (Figure 1). From this viewpoint, the individual receives the greatest attention.

From the job-demand perspective, however, stress results from the joint effects of the demands of work and the range of freedom (control) available to the worker facing those demands (e.g., Karasek, 1981, 1979). According to this perspective the primary source of stress lies within the
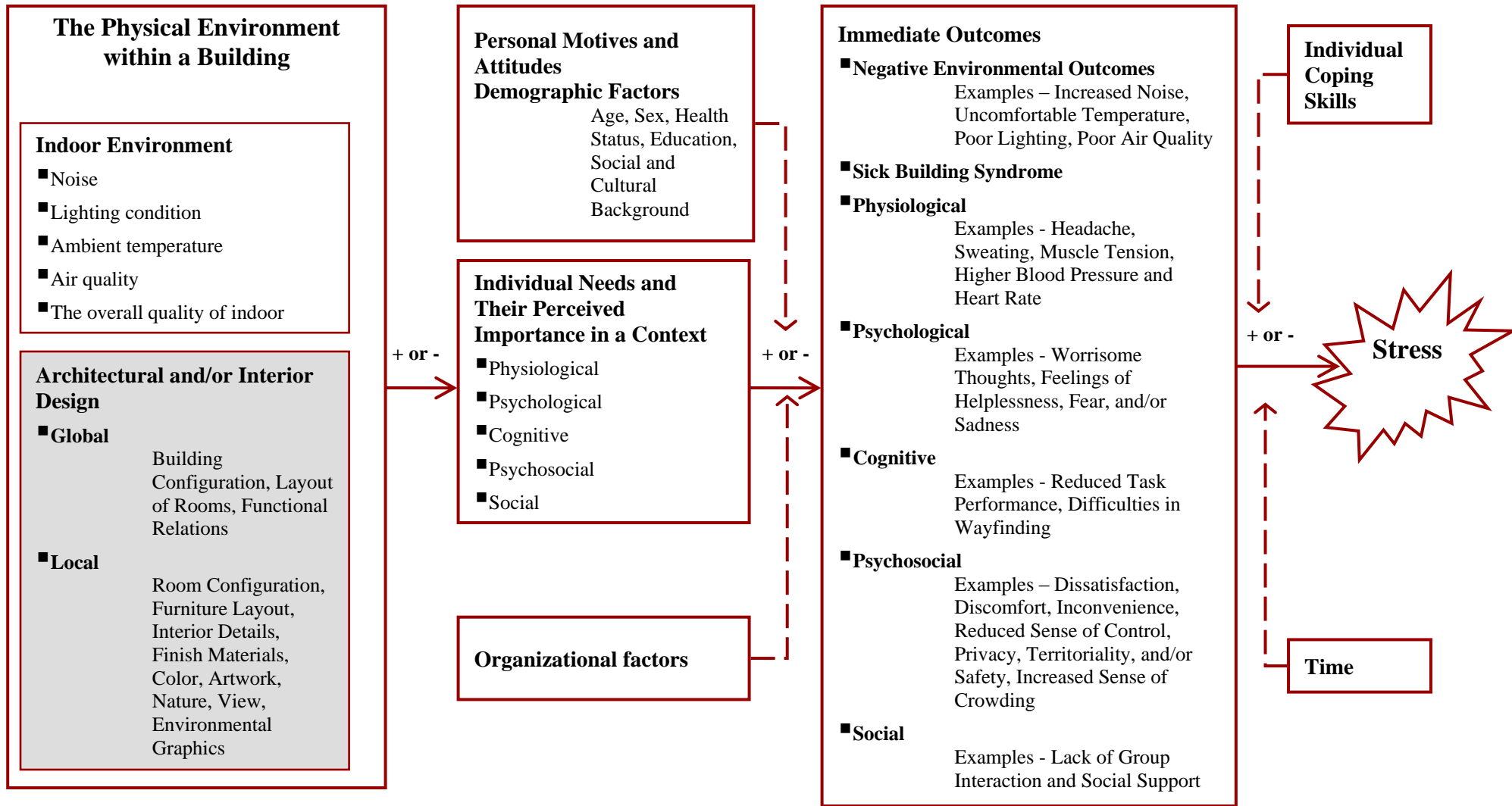
The Physical Environment within a Building

Indoor Environment
- Noise
- Lighting condition
- Ambient temperature
- Air quality
- The overall quality of indoor

Architectural and/or Interior Design
- **Global**

  Building Configuration, Layout of Rooms, Functional Relations

- **Local**

  Room Configuration, Furniture Layout, Interior Details, Finish Materials, Color, Artwork, Nature, View, Environmental Graphics

+ or -

Personal Motives and Attitudes
Demographic Factors

Age, Sex, Health Status, Education, Social and Cultural Background

Individual Needs and Their Perceived Importance in a Context
- Physiological
- Psychological
- Cognitive
- Psychosocial
- Social

Organizational factors

+ or -

Immediate Outcomes
- **Negative Environmental Outcomes**

  Examples – Increased Noise, Uncomfortable Temperature, Poor Lighting, Poor Air Quality

- **Sick Building Syndrome**
- **Physiological**

  Examples - Headache, Sweating, Muscle Tension, Higher Blood Pressure and Heart Rate

- **Psychological**

  Examples - Worrisome Thoughts, Feelings of Helplessness, Fear, and/or Sadness

- **Cognitive**

  Examples - Reduced Task Performance, Difficulties in Wayfinding

- **Psychosocial**

  Examples – Dissatisfaction, Discomfort, Inconvenience, Reduced Sense of Control, Privacy, Territoriality, and/or Safety, Increased Sense of Crowding

- **Social**

  Examples - Lack of Group Interaction and Social Support

Individual Coping Skills

+ or -

Stress

Time

Figure 1: A conceptual framework describing how the physical environment may set in motion a process leading to stress.

5

characteristics of the work itself. It assumes that most individual workers are physically and intellectually capable of performing the required activities. Even considering the variability between individuals, demands within workplace rarely exceed the capabilities of most workers. Thus, the source of stress is to be found in the work that simultaneously presents demands and restricts the options of workers for responding to those demands.

In contrast, the conceptual framework presented here puts environmental researchers in the forefront by suggesting that, in many cases, the physical environment may trigger processes leading to stress by the ways in which it affects individual and/or workplace needs. This framework, however, does not imply that environmental researchers need to provide validation for all its propositions. In fact, it may be more prudent for them to leave it up to psychologists and/or clinicians to study how individual coping skills may affect the relationship between physiological needs and stress. Instead, the framework does imply that environmental researchers should at least provide evidence explaining why and how environmental design affects individual and/or work needs, because this may help make the argument that environmental design, in the end, has a role to play in stress. The primary purpose of this review is to gather any evidence that directly and/or indirectly supports the fact that environmental design can affect individual and/or work needs (i.e., the intermediate outcome variables). Its secondary purpose is to gather any additional evidence explaining the relationship between any outcome variables and stress.

2. SCOPE OF REVIEW

Since a large body of environmental research literature directly and/or indirectly supports the fact that environmental design can affect individual and/or work needs, we limit this review to the effects of indoor environmental variables only. These variables generally include noise, lighting, ambient air temperature, and air quality. This review also includes a body of literature that reports how different individual needs can be affected by the overall indoor environmental quality of a building or facility. The authors may present, in the future, another review looking at the role of architectural and/or interior design elements (the grey area in figure 1) in the process leading to stress.

Investigations in healthcare and office settings were exclusively chosen for this review and are presented separately. In general, articles published in or before the 1960's were not included in the study as healthcare and office settings have changed significantly. For example, office settings are much less noisy than they were in the 1960s or before. Very few office or hospital buildings were totally mechanically-ventilated prior to the 1960s. Although controlled research of the 1960s and 1970s in either setting on general health related issues, for example the effects of noise on human health, should still be

valid, this body of research must be viewed with caution as research techniques and methods have evolved significantly since the 1960s.

Several key words and search terms were used in various different combinations to locate relevant literature for this review. For example, a list of terms used with *noise* included: stress, health, adverse effects, office, office setting, office environment, office worker, knowledge worker, hospital, healthcare setting, health facility environment, inpatient, patient, nurses, hospital staff, hospital visitor, patient family, privacy, acoustic privacy, control, environmental control, interaction, social interaction, annoyance, distraction, task performance, and satisfaction.

Most articles retrieved and/or reviewed were obtained from peer-reviewed journals and conference proceedings. Only papers with clear research methods including a clear description of what was measured and how it was measured, and in which no obvious confounds existed in the research design, were included in the study. The physics of sound, lighting, air temperature, and air ventilation was considered beyond the scope of this review, and was therefore omitted. Both laboratory and field studies were included for more general findings as well as findings related to these two settings. The authors acknowledge the fact that many more sources may exist in the literature than what have been mentioned in this paper. In the cases where the authors know for sure that the other supporting sources exist and mention only a few, they use the following reference format within the text -- e.g., Nagar & Pandey, 1987.

3. NOISE

3.1. The effects of noise in office settings

The literature on the effects of noise in office setting is substantial. In general, several non-physical characteristics of sound have shown to cause stress in offices and other workplaces. For example, unpredictable sounds tend to be more stressful (Glass & Singer, 1972; Sundstrom, 1986). Constant noise is easier to get used to (Kjellberg, et al., 1996). Unnecessary noise is perceived to be more harmful (Graeven, 1975). Controllable noise causes less frustration and has less negative effects on performance (Glass, Reim, & Singer, 1971). Sounds that are generated by others, or unpredictable sounds (e.g., telephone rings) are considered uncontrollable, hence more stressful (Kjellberg & Landström, 1994). Intelligible speech is more distracting than unintelligible speech or sounds with no information content (Boyce, 1974; Sundstrom et al., 1994). People talking in the background and telephones ringing have been cited most frequently as the primary sources of annoyance in offices (Boyce, 1974; Nemecek and Grandjean, 1973; Sundstrom et al., 1994).

Some researchers also claim that it is not the overall ambient sound level that determines annoyance ratings, but intermittent peak noises that fluctuate above the average levels (Hay & Kemp, 1972; Keighley, 1970; Kjellberg & Landström, 1994). In an investigation by Kjellberg and Landstrom, occupants were asked to complete a questionnaire as well as to rate their noise annoyance on a scale of 0 to 100 three times each day for five days. The study found that the most frequently identified annoying-sounds were speech, impact noise, and machine noise. Annoyance did not change over the course of the day but there was a tendency for lower annoyance later in the week (Landström et al., 1998).

Landström et al. (1995) studied the relationship between noise annoyance and frequency. 439 participants were exposed to one of three frequency- characteristic groups (low-frequency, mid-frequency and high frequency), and were asked to rate noise annoyance in their workplace. Participants' workplaces varied from offices to labs to industry. Low-frequency noise was below 200 Hz; mid-frequency between 200 Hz and 2000 Hz; and high- frequency was above 2000 Hz. Sound levels in these workplaces were generally between 50 and 65 dB(A), with total exposure levels ranging from 45 dB(A) to 85 dB(A). The highest noise annoyance ratings were obtained for the high-frequency group and the lowest for the low-frequency group. The authors concluded that "the results agree with previous studies indicating that the tonal components might increase annoyance levels" (Landström et al., 1995, p. 274).

Kjellberg et al. (1996) studied how factors such as predictability, controllability, necessity, information content, ongoing activity, and individual differences contributed to feelings of noise annoyance in workplaces. Three-hundred eighty six participants in three different types of workplaces rated their noise annoyance levels. The results indicated that the sound level and self-rated necessity of the noise were mostly related to annoyance ratings. Concerning predictability and controllability, it was found that annoyance was greater for machines used by others as compared to machines used by the person reporting.

Veitch et al. (2002) investigated the effects of noise level and spectrum on acoustic satisfaction. The experiment was conducted in a mock-open office consisting of 6 open-plan workstations, a shared space, and printers at both ends of the room. Participants were exposed to different controlled sound conditions, and were asked to complete a satisfaction rating for each sound condition. The study found that the effect of noise varied for different spectra. Increasing the noise level reduced speech intelligibility, but the effect was greater for high frequencies. Sound spectrum, however, did not moderate the effect of noise level on acoustic satisfaction.

Regarding task performance, it is reported that exposure to noise may lead to decrements in task performance (e.g., Glass & Singer, 1972; Cohen, 1978), or highly variable performance (e.g., Fisher, 1972; Cohen, 1979); that noise hinders the performance of complex tasks more than it hinders the

performance of simple tasks (e.g., Nagar & Pandey, 1987); that when one of several tasks is more important, noise tends to increase the effort expended on less important tasks; and that novel or unusual noise interferes with efficiency on most tasks (e.g., Broadbent, 1971, 1979).

Several studies report the effects of noise on various psychosocial outcomes. According to these studies, people are most comfortable if they can control noise to suit their own requirements (e.g., Gerlach, 1974); and individual stress may increase when noise cannot be controlled by an individual, (e.g., Cohen et al., 1991). Other studies report that environmental stress caused by extreme noise can lead to insensitivity to social cues and negative reactions to others at workplaces (e.g., Cohen & Lezak, 1977; Griffitt, 1970; Griffitt &Veitch, 1971; Korte, et al., 1975; Mathews & Canon, 1975; Page, 1977).

3.2.   The effects of noise in healthcare settings

Available empirical evidence supports that noise in healthcare settings creates stress (Ulrich, et al., 2004). Hospitals are noisy places, with levels far exceeding WHO guideline values: WHO specifies 35 dB(A) or less for background noise, but research finds 45 dB(A) to 68 dB(A). WHO specifies 40 dB(A) or less for nighttime peak, but research finds 80 dB(A) to 90dB(A) (e.g., Aaron et al., 1996; Allaouchiche, Duflo, Debon, Bergeret, & Chassard, 2002; Berglund, Lindvall, & Schwela, 1999; Busch-Vishniac, et al., 2005; McLaughlin, McLaughlin, Elliott, & Campalani, 1996; Robertson, Cooper-Peel, & Vos, 1998). Common sources of noise in healthcare settings include telephones, alarms, trolleys, ice machines, paging systems, nurse shift change, staff caring for other patients, door closing, staff conversations, and patient crying out or coughing (Ulrich, Lawson, & Martinez, 2003).

Topf (1992a) measured nighttime sound levels at the head of an occupied bed adjacent to a nurses' station in an eight-bed dormitory-style cardiothoracic CCU. The study yielded a minimum of 50, a maximum of 86.8, and average of 56.3 dB(A) at the location. Cropp et al. (1994) counted 33 different audio signals in a respiratory CCU. Ten were critical alarms requiring immediate nursing action, while the others did not require immediate action and/or were unnecessary.

Studies in healthcare settings show that high sound levels can have significant effects on annoyance and stress (Bayo, Garcia, & Garcia, 1995; Biley, 1994; Blomkvist et al., 2005; Hweidi, 2007; Morrison et al., 2003; Norbeck, 1985; Zahr & de Traversay, 1995). Topf (1992b) reports a controlled study involving 105 female volunteers, who slept or attempted to sleep overnight in a simulated CCU environment. The results of the study showed that CCU sounds caused greater subjective stress and that CCU sound levels independently accounted for 54% of the variance in subjective stress.

In a study involving 11 nurse volunteers, Morrison et al. (2003) collected an audiogram, questionnaire data, salivary amylase, and heart rate of the nurses in a quiet room. Then, each nurse was observed for a 3-hr period during patient care. During this period, heart rate and sound level were recorded continuously; and saliva samples and stress/annoyance ratings were collected every 30 minutes. Higher average sound levels significantly predicted higher heart rates, greater subjective stress, and annoyance.

Studies also show that noise is a major source of sleep disruption, hence discomfort, in healthcare settings (Freedman, Kotzer & Schwab, 1999; Gabor et al., 2003; Parthasarathy and Tobin 2004; Southwell & Wistow, 1995; Topf & Davis, 1993; Topf, Bookman & Arand, 1996; Topf & Thompson, 2001; Yinnon et al., 1992). Topf (1992a) reports a controlled study of subjective stress due to noise. 105 female volunteers were randomly assigned to three groups--instruction in personal control over noise, no instruction in personal control over noise, or a quiet condition. Subjects in the two noise conditions heard audiotape-recorded CCU nighttime sounds while attempting to sleep overnight in the laboratory. The results showed evidence for a causal relationship between CCU sounds and poorer sleep.

Regarding the mediating role of personal factors on the effects of noise in healthcare settings, studies show that postoperative patients, CCU nurses, and laboratory subjects with a greater general sensitivity to noise may be more affected by hospital noise-induced subjective stress (Topf, 1985, 1989). A survey of 150 postoperative patients showed that being able to present one's self in a socially favorable light was significantly linked with less complaining about noise on questionnaire items (Topf, 1985). Another survey of 100 critical care nurses found that less commitment to work was significantly linked with greater subjective disturbance due to hospital noise (Topf, 1989). Studies in hospital settings also suggest that women are more reactive to sound than men (Hansell, 1984); and adolescents tolerate greater sound levels than the elderly (Topf, 1984, 2000).

Regarding staff outcomes, Topf & Dillon (1988) showed that noise-induced stress in nurses affects emotional exhaustion or burnout. Healey, et al. (2007) showed that noise may also affect medical errors committed by staff. Blomkvist et al. (2005) examined the influence of different acoustic conditions on the work environment and the staff in a coronary critical care unit (CCU). The researchers collected psychosocial work environment data from start and end of each of the morning, afternoon, and night shifts for a one-week baseline period and for two four-week periods during which either sound reflecting or sound absorbing tiles were installed. The results showed that improved reverberation times and speech intelligibility during the study period when sound absorbing tiles were in place positively affected the work environment; and the afternoon shift staff experienced significantly lower work demands and reported less pressure and strain.

Regarding patient outcomes, Hagerman et al. (2005) found that poor acoustics had important detrimental physiological effects on rehabilitation. One clinical survey showed that greater pain and more medication were linked with greater noise-induced subjective stress (Simpson et al., 1996). Studies also showed that infants exposed to continuous noise in NICUs suffered some hearing loss or were slow in their growth and development (American Academy of Pediatrics, 1997). Even though researchers unequivocally acknowledge the importance of sound in the very early stages of human growth and development, in a supplement to the Journal of Perinatology edited by M Kathleen Philbin (2000) many contributing authors note that a consistent problem with the research reporting effects of sound on preterm infant behavior and development is that the ambient sound in nursery research settings is neither described nor considered. Yet, all reports of nursery sound show high levels without respite periods quiet.

Office Settings	Healthcare Settings
- Non-physical characteristics of sound including its usefulness, predictability, and intelligibility may help determine the effects of noise among office workers. - Most annoying sources of sounds in offices include people, telephones, and mechanical equipment. - Individual need for noise is also related to individual annoyance ratings. - Intermittent peak noises often determine worker annoyance. - Tonal components, both high and low frequency, may also cause annoyance. - The effects of noise level on speech intelligibility are stronger in high frequencies. - The effects of noise on task performance may vary depending on the nature and complexity of tasks. - People are more comfortable if they can control noise when needed. Annoyance is greater for noise created by machines used by others. - People who work in noisy places may become insensitive to social cues.	- Hospitals are very noisy places, with noise levels far exceeding the WHO guidelines. - Sources of noise in hospitals are numerous. Most of these sources are often unnecessary, and can easily be eliminated. - Noise is a major source of sleep disruption and discomfort in healthcare settings. - Noise level in healthcare settings is related to subjective stress. Subjective stress caused by noise may also partly depend on individual's sensitivity to noise. - When a patient is able to present herself in a socially favorable manner, she complains less about noise. - Noise-induced stress in nurses correlates with emotional exhaustion or burnout. - In general, women are more reactive to noise than men. - Important gains in the psychosocial work environment of healthcare can be achieved by improving room acoustics. - Greater noise-induced stress may be linked to slower growth and development among infants, and greater pain and use of larger doses of pain medication among pain patients. - Many reported studies on the effects of sound on preterm newborns do not take into account the ambient sound in nursery settings; as a result, it may remain as an unreported confounding variable in these studies.

Table 1: Major findings on the effects of noise in office and healthcare settings

4. LIGHTING

4.1. The effects of lighting in office settings

The direct psychological and physiological effects of lighting in workplaces are very well-studied. In fact, direct physiological and psychological benefits of daylight in workplaces are so great that many countries in Europe require that workers be within certain distance from a window. Markus (1967) reported that approximately 96% of respondents preferred to work under natural light as opposed to electric lighting. Additionally, approximately 86% of the respondents preferred having sunshine in their office year round as opposed to only one season of the year or not at all. Markus (1967) also reported that employees sitting near windows were more content, whereas those sitting further away from the windows complained more. Oldham and Fried (1987) reported that when offices were darker, employees were more likely to leave offices when they had a choice, at lunchtime, breaks, and so forth. Franta and Anstead (1994) showed that a lack of daylighting or insufficient light caused headaches, seasonal affective disorder (SAD), and eyestrain. Heerwagen et al. (1998) reported that daylighting created a more positive mood amongst workers leading to better workplace outcomes. Leather et al. (1998) found that sunlight penetration had positive effects on workers. Improvements in productivity, a decrease in accidents, an increased level of mental performance, improvements in sleep quality, and an increase in morale among night shift workers have been attributed to better lighting conditions (Luo, 1998).

The published literature, while limited, is consistent with the expectation that performance of work that depends very highly on excellent vision, such as difficult inspections of products, will vary with lighting levels and quality. For example, Romm and Browning (1994) reports a 6% increase in the performance of postal workers during mail sorting in increased lighting conditions. Increased lighting has shown to increase arousal level and alertness for shift workers (Campbell & Dawson, 1990). More rapid production of drawings by a drafting group after bright reflections were reduced has also been reported (NEMA, 1989). Some studies have failed to identify any significant effects of illuminance on aspects of reading performance, such as reading comprehension, reading speed, or accuracy of proofreading (Veitch, 1990; Smith and Rea, 1982). Other studies have found illuminance to significantly influence reading performance primarily associated with unusually low light levels or reading material with small, poor-quality, or low-contrast type (Smith and Rea, 1979). Low levels of illuminance seem to have a more definite adverse influence on the performance of older people (Smith and Rea, 1979; NEMA, 1989).

A few studies have examined the influence of different lighting systems on self-reported productivity or on cognitive task performance (e.g., Hedge et al., 1995). Katzev (1992) studied the mood and cognitive performance of subjects in laboratories with four different lighting systems. The type of

lighting system influenced occupant satisfaction and was associated with better reading comprehension. However, performance in detecting writing errors, typing, and entering data was not significantly associated with the type of lighting system. The luminous flicker of fluorescent lamps, which can be reduced or eliminated by replacing magnetic ballasts with digital ballasts, has shown to have affected visual performance; caused visual discomfort and general stress (Wilkins et al. 1989); and triggered migraine among office workers (e.g., Kuller & Laike, 1998; Veitch & McColl, 1995; Veitch & Newsham, 1998).

Several studies have shown some effects of lighting on social relations and/or interpersonal conflicts. For example, in one workplace study subjects exposed to warm white light reported stronger preferences for resolving interpersonal conflicts through collaboration and weaker preferences for resolving conflicts through avoidance than subjects exposed to cool-white light (Baron, Rea & Daniels, 1992).

4.2. The effects of lighting in healthcare settings

The healthcare research literature focuses primarily on the direct psychological and physiological effects of lighting in healthcare settings, with the following important findings: 1) light modulations may help reduce heart rate, activity level, and respiration rates among infants (Brandon, Holditch-Davis and Belyea, 2002; Blackburn & Patteson, 1991; Shepley, 2004); 2) the amount of sunlight in hospital rooms may influence patients' mental health and intake of pain drugs (Walch et al., 2005); 3) bright light may be more effective than placebo in treating winter depression (Eastman et al., 1998); and 4) bright light is effective in reducing depression among patients with bipolar disorder or SAD (Beauchemin & Hays, 1996; Benedetti, et al., 2001; Lewy et al., 1998; Lovell, Ancoli-Israel, & Gevirtz, 1995; Terman, et al., 2001; Van Someren, et al., 1997; Wallace-Guy et al., 2002)..

In their study on the length of hospitalization involving 415 unipolar and 187 bipolar depressed inpatients, Benedetti et al. (2001) reported that bipolar inpatients exposed to direct sunlight in the morning) had a mean 3.67-day shorter hospital stay, but no effect of sunlight was seen for unipolar patients. In other studies, it was found that mortality rate might be higher in dull rooms, with sex having differential effects (Beauchemin & Hays, 1996, 1998). Studies also showed that Alzheimer's patients who were exposed to bright lights during the day had improved circadian rhythms and were less prone to depression. As a result, the time demands of caregivers in Alzheimer's units were reduced (Satlin et al., 1992).

Cool, flickering fluorescent lights may have different negative health effects. For example, autistic children became more distracted under fluorescent light (Colman et al., 1976). Flickering fluorescent lights have been found to trigger epileptic seizures. People with Alzheimer's disease became agitated under fluorescent lighting (Carpman & Grant, 1993). For these negative effects, cool-white fluorescent lights are banned in healthcare settings in Germany (Walker, 1998). Cool fluorescent lights have more of the yellow to red portion of the visible light spectrum. They lack the blue portion, which is the most important part for humans and is best provided by natural light (Liberman, 1991). Full-spectrum fluorescent lights with digital ballast may help eliminate most problems related to cool, flickering fluorescent lights.

Studies suggest that proper lighting is very important for residents in assisted-living facilities. Proper lighting can allow the elderly to function more independently by improving social contact, appetite, mood, self-confidence, and anxiety levels. Older people may require more light to obtain the proper visual sharpness (Jones, 1996). One third of people 70 years old or older have macular degeneration. Glare increases the degenerating rate caused by the disease (Carpman & Grant, 1993). Falls, one of the most common and dangerous health problems for the elderly, can also be attributed to improper or inadequate lighting. Studies show that some light-deprived nursing home residents wake up and fall asleep as many as 37 times a night (Jones, 1996).

Some findings on the effects of lighting on task performance in healthcare settings are also reported in the literature. For example, in at least two studies the rate of prescription-dispensing errors was associated with the level of illumination (Buchanan et al., 1991, Roseman & Booker, 1995a). In another study in Alaska, it was found that fifty-eight percent of all medication errors among hospital workers occurred during the first quarter of the year when daylight hours were less (Roseman & Booker, 1995b). In yet another study, it was shown that by shifting the circadian rhythms of the nurses with the use of brighter lights, nurses were able to improve the number of correct answers given in a standardized exam and decrease the time to take the test (Dilouie, 1997).

Office Settings	Healthcare Settings
• There are many direct physiological and psychological benefits of daylight in workplaces. • Lighting may impact worker performance directly because of its effects on vision and indirectly because of its effects on attention and arousal. • The level of illuminance impacts the activities of older people more. • Some lighting systems support self-reported	• There are several direct physiological and psychological effects of daylighting on patients, both young and old. • Particular patient groups, such as patients with mental disorders and Alzheimer's disease, can be extremely benefited from daylighting. • Cool fluorescent lighting has may negative effects on some patients. Full spectrum fluorescent light may help reduce these negative effects.

productivity and cognitive task performance better than the others. • The flickers of fluorescent light with magnetic ballasts have several negative effects on workers. These problems, however, can be solved using digital ballasts. • Lighting has shown to have some effects on social relations. • Workers may feel uncomfortable if they are unable to control lighting levels to suit their own requirements.	• Proper lighting can allow older people to function more independently by improving social contact, appetite, mood, self-confidence, and anxiety levels. • Lighting has shown to have some effects the performance of workers in healthcare settings.

Table 2: Major findings on the effects of lighting in office and healthcare settings

5. AMBIENT TEMPERATURE

5.1. The effects of ambient temperature in office settings

Ambient temperature is a predominant stressor in office buildings. In several studies, 'too hot' and 'too cold' were the overwhelming majority of unsolicited complaints (77%) in office buildings (Federspiel 1998, 2000, 2001). In a study on the relation between temperature satisfaction ratings expressed on a questionnaire and unsolicited complaint rates recorded in a maintenance database, Wang, Federspiel, and Arens (2005) reported significantly positive correlations between the percent dissatisfied with temperature and the complaint rate.

Laboratory studies by the New York State Commission (1923) found that performance of manual work was significantly influenced by temperature but that performance of mental work was not. However, a re-analysis of a portion of the Commission's data (Wyon, 1974) found that subjects performed 18% to 49% more typewriting work at 20°C compared to 24°C. Meese et al. (1982) reported that in a simulated factory works factory-workers' showed lower performance on eight out of fourteen tasks at a lower temperature (18°C). Federspiel et al. (2002) reported a quasi-experiment in a telephone call center where talk time on the telephone and wrap-up time after each call were measured. A multivariate analysis of individual performance averaged over worker shifts of approximately 8 hrs showed that both measures of performance decreased in the highest category of temperature (>25.4° C).

Witterseh et al. (2002) reported findings of a controlled study in an office/laboratory setting where temperature was among the conditions varied with other factors held constant. Subjects performed standardized performance tests and reported self-assessed performance and symptoms on a questionnaire. As temperature increased from 22° to 26° to 30° C, performance on tests did not change, although

subjects reported decreased self-estimated performance, and increased difficulty thinking and concentrating.

Other studies showed that heat reduced attraction and increased the sense of crowding; and crowding, in combination with heat, worked to further reduce attraction (Griffitt, 1970; Griffiths & Boyce, 1971; Griffitt & Veitch, 1971). If temperature was high enough, aggression was relatively absent, either because of lethargy, or flight responses or both. At an intermediate temperature, there was a facilitating effect of heat on aggression. Other studies in workplaces showed that environmental stress caused by uncomfortable heat could lead to insensitivity to social cues and negative reactions to others (Korte, et al., 1975). However, the effects of heat on helping and/or social interaction remain contradictory in the literature (Cunningham, 1979; Schneider et al., 1980).

In northern European workplace studies, a linear relationship between the symptoms of Sick Building Syndrome (SBS) and room temperatures above 22°C has been a consistent finding (e.g., Reinikainen & Jaakkola, 2001; Heinonen, & Seppaenen, 1989). (See below for additional information on SBS.) However, Heinonen, and Seppaenen (1989) also found that SBS symptoms increased both when the temperature was considered too cold and too warm, indicating that these symptoms can also indicate a general dissatisfaction with the temperature.

5.2. The effects of ambient temperature in healthcare settings

Very few studies have been reported on the effects of ambient temperature in healthcare settings. In these studies, temperature was only one of many factors of the indoor environment being studied. In one study on the relationships between the symptoms of SBS and environmental factors, no effect of temperature on SBS is found (Nordström, Norbäck & Akselsson, 1995a), contradicting some of the findings reported above. Although there are many doubts as to the applicability of the standard thermal comfort assessment techniques to hospital ward areas, a study by Smith and Rae (1977) gives a good indication that patients, in general, may prefer steady-state conditions, which include air temperature between 21.5° and 22° C and a relative humidity of between 30% and 70%, where the air velocity was less than 0-1 m/s and the mean radiant temperature was close to air temperature.

Office Settings	Healthcare Settings
• Workers make more unsolicited complaints and are less satisfied when it is hot or cold in workplaces. • In general, studies show that hot or cold may reduce the overall individual capacity to perform a task.	• No major finding was reported on the effects of ambient temperature in healthcare settings except one suggesting that patients preferred air temperature between 21.5° and 22° C.

• At higher temperature, individual may report decreased self-estimated performance and increase difficulty thinking and concentrating. • High ambient temperature has several negative effects on social relations, such as insensitivity to social cues, increased sense of crowding, and negative reactions to others. • Ambient temperature above 23°C may increase the symptoms of sick building syndrome. However, when the temperature is considered too cold and too warm an excess of SBS symptoms may occur.	

Table 3: Major findings on the effects of ambient temperature in office and healthcare settings

6. AIR QUALITY

6.1. The effects of air quality in office settings

Air supply, odor, and pollutants determine the air quality within a building. Numerous workplace studies have shown that air quality can cause stress among workers. In a review of current literature, Seppanen, Fisk, and Mendell (1999) found that almost all 20 ventilation studies involving close to 30,000 subjects reported that ventilation rates below 10 Ls^{-1} per person in all building types were associated with statistically significant worsening in one or more health or perceived air quality outcomes. They also found that about half of the 21 carbon dioxide studies involving 30,000 subjects suggest that the risk of SBS symptoms continued to decrease significantly with decreasing carbon dioxide concentrations below 800 ppm (parts per million).

Wargocki and Fanger (1997) studied air quality in three groups of naturally ventilated offices with felt carpet, linoleum, or polyolefine flooring. An assessment of air quality by an independent panel of subjects upon entering the offices and after 1 hour of occupation indicated less dissatisfaction in the offices with polyolefine flooring, which also had the lowest pollution load on the air. Pejtersen et al. (1999) reported a significant decrease of adverse perceptions of air quality among occupants in an office building in Denmark which was renovated by substituting an old polyamide boucle´ carpet with new low-emitting vinyl. In another intervention study in a naturally ventilated office building in Denmark, air pollution was reduced by substituting polyamide boucle´ carpet, an important source of sensory pollution, by polyolefine flooring. Following the intervention, air quality caused less dissatisfaction, as assessed both by an independent panel of subjects and by the occupants of the building (van Beuningen et al., 1994).

Studies on the direct effects of air pollution on human performance in office buildings provide very little conclusive results. For example, no impaired performance in neurobehavioural tests was observed in healthy individuals after they were exposed to a highly concentrated mixture of 22 volatile organic compounds (VOCs) generally emitted from building materials in Denmark (Otto et al.,1992, 1993; Mølhave, 1982; Mølhave et al., 1986). On the other hand, chamber exposure to the same VOC mixture decreased memory for digits in a standard digit span test when healthy subjects who claimed to suffer from typical indoor climate symptoms were tested instead (Mølhave et al., 1986). Toluene levels of 100 ppm were shown to significantly reduce manual dexterity, performance in color discrimination tasks, and visual acuity in industrial settings (Bælum et al., 1985). The results of Bælum et al. are of little relevance to indoor air quality in offices, since toluene concentrations in non-industrial spaces are usually 1,000-fold lower (Brown et al., 1994).

Wargocki et al. (2000) reported that performance of simulated office tasks improved monotonically with increasing ventilation rates. On average, for each doubling of ventilation rate in the range between 3 and 30 Ls^{-1} per person, work on specific office tasks increased from 1.1 to 2.1%. However, Fang et al. (2002), in a simpler comparison of two ventilation rates, using the same controlled environment used in Wargocki et al. (2000), found no differences in task performance. Nunes et al. (1993) observed impaired mental task performance among office workers who reported any SBS symptoms in a mechanically ventilated building in Canada (Wyon, 1996). In contrast, studies performed by the New York State Commission (1923) showed no effect of very high level carbon dioxide (3,000–4,000 ppm) on the performance of simulated office work.

Wargocki et al. (1999) suggested that reducing indoor air pollution may improve the comfort, health, and productivity of building occupants. Milton et al. (2000) found that substantially high ventilation rates above current recommended levels were consistently associated with decrease in short-term sick leave. Other air quality studies in workplaces report the following findings: 1) lower supply velocity is more comfortable (Jiang, Chen, & Moser, 1992); 2) under low-motivation task-performance conditions, odor may cause greater annoyance (Stone, Breidenbach & Heimstra, 1979); 3) exposure to gaseous pollutants such as nitrogen dioxide and sulfur dioxide may affect human sensory processes, impairing darkness adaptation and brightness sensitivity (Izmerov, 1971); 4) there are some relationships between odor and willingness to help (Cunningham, 1979); and 5) carbon monoxide can severely impair human performance (National Academy of Sciences, 1977).

6.2. The effects of air quality in healthcare settings

Several studies in healthcare setting have linked air quality and infection rates to the types of air filter, directions of airflow, air pressure, air change rates, humidity, and ventilation system cleaning and maintenance regimes (Lutz, 2003; McDonald et al., 1998). For example, studies found the least bacterial air contamination in laminar airflow rooms and reduced contamination in ultraclean rooms in comparison with conventional rooms. Similar results were obtained with culture of air for fungi (Artlet et al., 1989; Barnes & Rogers, 1989). Studies also found that the higher the air change rate, the lower the airborne bacteria count (Ayliffe, Collins & Taylor, 1982). Additionally, studies found that humidity was an important factor affecting concentrations of airborne bacteria (Obbard & Fang, 2003).

Several studies suggest a link between hospital construction activities and airborne infection outbreaks (Humphreys et al., 1991; Iwen et al., 1994; Loo et al., 1996; Opal et al., 1986; Oren, Haddad, Finkelstein, & Rowe, 2001). Opal et al. (1986) reported high spore counts within and outside construction sites in a hospital. In another study by Oren et al. (2001), it was reported that a nosocomial (hospital-induced) outbreak of Invasive Pulmonary Aspergillosis (IPA) occurred in acute leukemia patients treated in a regular ward with natural ventilation during extensive hospital construction and renovation. The observed infection rate was 50 percent. At this point, some of the patients were moved to a new hematology ward with high-efficiency particulate air (HEPA) filters. During the following three years, none of the patients hospitalized exclusively in the hematology ward developed IPA, although 29% of leukemia patients still housed in the regular ward contracted IPA. A study by Mahieu, et al. (2000) also suggested that HEPA filters were able to reduce airborne contaminants in spaces near construction and renovation sites.

Studies have consistently shown that immuno-compromised and other high-acuity patients have lower incidence of infection when housed in a HEPA-filtered isolation room (Passweg et al., 1998; Sherertz et al., 1987). In one of these studies, bone-marrow transplant recipients were found to have a tenfold greater incidence of nosocomial Aspergillus infection, compared to other immuno-compromised patient populations, when assigned beds outside of a HEPA-filtered environment (Sherertz et al., 1987). In fact, the evidence for the effectiveness of HEPA filter in reducing airborne contaminants is so great that they are suggested for healthcare settings by the CDC and HICPAC, and are either required or strongly recommended in all construction and renovation areas (Sehulster & Chinn, 2003).

Several studies deal with healthcare employees' risk of contracting infectious diseases from patients due to airborne contamination. A recent study in China found that isolating SARS cases in wards with good ventilation could reduce the viral load of the ward (Jiang et al., 2003). An evaluation of 17 hospitals in Canada involving all personnel who worked at least two days per week in the respiratory and

physiotherapy departments showed that tuberculosis (TB) infection among healthcare workers was associated with ventilation of less than two air exchanges per hour (Menzies et al., 2000). Another study in Norway involving 115 females who worked at 36 geriatric nursing departments found significant decrease in nasal patency (i.e., minimum cross-sectional area) in the presence of *Aspergillus fumigatus* in ventilation supply and elevated room temperatures (Smedbold et al., 2002).

Office Settings	Healthcare Settings
• Ventilation rates below 10 Ls-1 per person in all building types may be associated with statistically significant worsening in one or more health or perceived air quality outcomes. • Increases in ventilation rates may be associated with significant decreases in the prevalence of sick building syndrome (SBS) symptoms or with significant improvements in perceived air quality. • The risk of sick building syndrome symptoms may decrease significantly with carbon dioxide concentrations below 800 ppm. • Studies on the direct effects of air pollution on human performance in office buildings provide very little conclusive results. However, there are many indirect negative effects of air quality on worker's performance. • Substantially higher ventilation rates may decrease short-term sick leave. • Low supply velocity is generally more comfortable. • Odor may have some effects on social relation.	• Hospital infection rates are related to the types of air filter, directions of airflow, air pressure, air change rates, humidity, and ventilation system cleaning and maintenance regimes. • Hospital construction and renovation activities are related to airborne infection outbreaks. • Immuno-compromised and other high-acuity patient groups have lower incidence of infection when housed in a HEPA-filtered isolation room. HEPA filters can reduce airborne contaminants in spaces near construction and renovation sites as well. • Healthcare employees' are at risk of contracting infectious diseases from patients due to airborne contamination.

Table 4: Major findings on the effects of air quality in office and healthcare settings

7. THE OVERALL QUALITY OF THE INDOOR ENVIRONMENT

7.1. The effects of the overall quality of the indoor environment in office settings

In relation to the overall indoor environment quality, the phenomenon that has been most frequently reported in the environmental research literature is the "Sick building syndrome" (SBS). Hence, we focus exclusively on this phenomenon in our review. SBS describes an increasingly common pattern of symptoms related to working in particular buildings. Core symptoms include lethargy, mucous membrane irritation, headache, eye irritation, and dry skin. All except skin symptoms should improve within a few hours of leaving a problem building (Burge, 2004). The World Health Organization now estimates that

30% of new or remodeled office buildings show signs of SBS, and that between 10% and 30% of the occupants of these buildings are affected by SBS (Lyles, et al., 1991).

Only a few objective tests exist to validate the symptoms of SBS. Most studies on SBS depend on self reported data. The main building factors related to SBS include fresh air ventilation rates, temperature, humidity, dust, and the microbial content of the air. It is quite likely that all these factors can contribute equally to the making of these symptoms.

Some studies show a relation between ventilation rate and SBS, while others show no relation (Mendell & Smith, 1990). In air conditioned buildings, low ventilation rates (less than 10 Ls^{-1} per person) are associated with increased symptoms (Seppanen et al., 1999). In mechanically ventilated buildings, without or without air conditioning, increased symptoms are associated with increased ventilation suggesting that pollutants from the mechanical plant are the dominant cause in these cases (Menzies et al., 1990; Jaakkola & Miettinen, 1995). Chamber experiments show less dry throat and less difficulty thinking clearly with increasing ventilation (Wargocki et al., 2000). Northern European studies consistently show that temperatures above 23°C increase SBS (Burge, et al., 1990; Jaakkola et al., 1989). Studies also show an association between the presence of a humidifier in the air conditioning circuit and SBS, rather than the reverse (Burge et al., 1987). VOCs (Volatile Organic Compounds), generally emitted from cleaners, paints, flooring materials, and adhesives during renovation, remodeling, repair, and regular building maintenance, have shown to cause SBS (e.g., Sundell et al., 1993; Ten Brinke et al., 1998).

Studies have shown both personal and psychosocial risk factors for SBS, in addition to those posed by the indoor environment of a building. Female gender (e.g., Apter et al., 1994; Brasche et al., 2001; Skyberg et al., 2003) and history of allergic disorders (e.g., Bjornsson et al., 1998; Hodgson, 1995) can be important risk factors for SBS. Psychosocial risk factors for SBS include work stress (e.g., Crawford and Bolas, 1996; Ooi et al., 1998), and personality (e.g., Runeson et al., 2003, 2004). A lack of environmental control may be yet another risk factor for SBS. Menzies et al. (1997) reported that giving individual workplace ventilation control reduced SBS over a prolonged period, despite a resulting increase in airborne dust and fungal spores and more variable temperatures. Skyberg et al. (2003) reported that daily visual display unit (VDU) work time, passive smoking, and psychosocial load were also relatively strong predictors of SBS.

In a study involving 877 subjects in 12 mechanically ventilated buildings, Haghighat and Donnini (1999) reported positive relationships between job satisfaction and satisfaction with office air quality, ventilation, work area temperature, and ratings of work area environment. In another study, Runeson et al. (2006) reported that high demand (i.e., having to do too much in a short period), low control (i.e., not

having enough influence over the way the work should be performed), and low support from coworkers and superiors may increase the risk of SBS among office workers.

Regarding task performance, Berglund et al. (1992) reported no effects on the performance of psychological tests when subjects occupied office buildings diagnosed as ''healthy'' or ''sick''. In this study, however, no significant difference was observed in the prevalence of SBS between subjects exposed to buildings assumed to be ''sick'' or ''healthy''. A review by Leinster and Mitchell (1992) claimed that building-related symptoms negatively affected self-reported productivity, but only if they averaged two symptoms per person or more. Self-reported productivity was also linked to the prevalence of SBS symptoms in studies of offices in the UK (Raw et al., 1990), as well as in the USA (Hall et al., 1991).

7.2. The effects of the overall quality of the indoor environment in healthcare settings

Sick Building Syndrome can be severe in healthcare settings with complex mechanical ventilation systems. Additional risk factors in healthcare settings are sterilizers, formaldehyde, acetone, benzene, toluene, anesthetic agents, and pharmacological agents. However, studies on SBS in healthcare settings have been few, and many confounding factors such as medical supplies, infected patients, and a more mobile workforce make any study on the subject matter difficult.

In a study involving 225 female hospital workers in eight hospital units in Sweden, Nordström, Norbäck and Akselsson (1995a) found that the prevalence of SBS symptoms differed from one unit to another, but was generally very high in all units. They also found that work stress and a lack of control of work conditions were among the predictors of SBS. In another study, Nordström, Norbäck and Akselsson (1995b) reported that complaints related to air dryness were more common in new and well-ventilated hospital buildings. Air dryness was also more common in buildings with damp concrete slabs. In contrast, complaints about odor and stuffy air were most prevalent in old buildings with a lack of outdoor air supply, and complaints about odor were more common in buildings with higher relative air humidity. Similar findings were also reported in a study involving four geriatric hospitals (Nordström, Norbäck, & Wieslander, 1999).

In a study involving 115 female nurses at 36 geriatric nursing departments, Smedbold et al., (2002) found that fungal contamination of air-supply ducts was a source of microbial pollution affecting the nasal mucosa. In an earlier study, Smedbold et al. (2001) found decreased break-up time (BUT) of the cornea in subjects working in hospitals situated in urban areas with heavy traffic, and in subjects working in departments with presence of *A. fumigatus*. In a study on microbiological airborne contamination in

different spaces in a general hospital in Bologna, Berardi and Leoni (1993) found that air microbial counts were higher in hospital wards than in hospital offices and laboratories. They also found that microbial contamination was not correlated with the air conditioning system.

Nordström, Norbäck, and Akselsson (1994) evaluated the effects of steam air humidification on SBS and perceive air quality during a four-month heating season. The study included 104 hospital employees in four new and well ventilated geriatric hospital units in Sweden. Two units had higher relative air humidity (between 40–45%), whereas the other two units served as controls with normal relative humidity (25–35%). After four months, 24% reported a weekly sensation of dryness in humidified units, compared with 73% in controls. No significant changes in symptoms of SBS or perceived air quality were found in the control group.

Mendelson, Catano, and Kelloway (2000) examined differences in stress, social support, and both physical and psychological symptoms among hospital personnel working in known SBS sites in Halifax, Nova Scotia (n = 297) with control employees working in relatively SBS-free settings (n = 228). They found more employees complained of poor air quality in SBS locations. They also found higher levels of organizational support and marginally higher levels of union support in SBS locations. Further analyses revealed that employees with higher role overload and greater family support but with lower levels of organizational support were more likely to report SBS symptoms.

Kelland (1992) examined the relations of SBS and work environments, as perceived by junior nursing and administrative staff, in two teaching hospitals in London. One of these hospitals was modern with artificial ventilation, and the other was old with naturally ventilation. In a questionnaire survey over a 2-month period, both staff groups at the modern site reported more SBS symptoms, inferior working environment, increased dryness and heat, and low environmental control. It was concluded that staff perceived the naturally ventilated hospital building more favorably than the artificially ventilated building.

Office Settings	Healthcare Settings
• Pollutants from the mechanical plant are the dominant cause for SBS in mechanically-ventilated buildings. • The risk factors for SBS include sex, age, personality, smoking, asthma, allergy and several psychosocial aspects of the work environment. • Job satisfaction and satisfaction with office show positive relationships with air quality, ventilation, work area temperature, and ratings of work area environment.	• Studies on SBS in healthcare settings have been few and sporadic because of many confounding factors. • Studies show SBS is generally high in hospitals. • Work stress and lack of control are among the predictors of SBS in hospitals. • Fungal contamination of air-supply ducts may be a source of microbial pollution in hospitals. • Air microbial counts may be higher in hospital wards than in hospital offices and laboratories.

• Workplace ventilation control reduces SBS symptoms over a prolonged period despite a resulting increase in airborne dust and fungal spores, and more variable temperatures. • High demand, low control, and low support from coworkers and superiors may increase the risk of SBS among office workers. • The effect of SBS on task performance is unclear.	• Health related complains are generally higher in hospital buildings with SBS. • SBS may not be solely dependent on environmental factors. Perceptions of poor air quality may be predicted by higher levels of role conflict, role overload, and organizational stress and lower levels of organizational support. • Hospital staff may perceive naturally ventilated hospital buildings more favorable that artificially ventilated buildings.

Table 5: Major findings on the effects of the overall quality of the indoor environment in office and healthcare settings

8. SOME GENERAL REMARKS ON THE AVAILABLE EVIDENCE

On the basis of this review, several interesting remarks can be made regarding the empirical work on the effects of indoor environment in healthcare and office settings. This review shows that a significant amount of work has been done in both settings on the physiological, psychological, and cognitive effects of noise. However, the amount of evidence on these effects is much greater in office literature. In general, studies on noise in healthcare settings has focused more on physiological outcomes such as sleep disruption, blood pressure and heart rate, while the studies in office settings has focused more on psychological and cognitive outcomes.

The greatest discrepancy, however, exists in the research related to psychosocial and social effects of noise including its effects on satisfaction, environmental control, social interaction, social support, and insensitivity to social cues. The amount of evidence on these effects, again, is much greater in office settings. Given the fact that noise is a great source of annoyance in healthcare settings, it is important to note that there are relatively few studies in healthcare settings related to psychosocial and/or social effects of noise. It is also important to note that most findings on the effects of noise in office settings may not translate well in healthcare settings because patients and their families may be more vulnerable to noise than healthy office workers.

The literature on the effects of lighting is ample in both healthcare and office settings. Studies in both settings unambiguously present the fact that daylight is important for human health. They also present other beneficial effects of daylight. The effects of cool fluorescent light with magnetic ballasts are also very well-studied in both settings, but some of these negative effects have already been reduced with the introduction of the full-spectrum fluorescent light with digital ballasts. Nevertheless, the evidence on

the positive effects of daylight and the negative effects of cool fluorescent light is so strong in the research literature that building codes in Europe and the USA promote the use of daylight and discourage the use of cool fluorescent light in both these settings. It is also important to note that most findings reported in the healthcare literature are related to older people with or without Alzheimer's disease. In this sense, then, a lot more research can be done regarding the effects of lighting on other patient groups in healthcare settings.

There is enough evidence in both office and healthcare literature on ambient temperature and physiological stress when conditions are either too hot or too cold. Very little empirical evidence on psychological, cognitive, behavioral, psychosocial, or social effects of ambient temperature can be found in healthcare settings. Though more empirical evidence can be found in office literature, the evidence here is uneven on the effects of ambient temperature. Many studies report the effects of temperature on task performance, environmental control and worker satisfaction. Only few studies report the psychological, behavioral and/or social effects of ambient temperature in office settings.

There are many studies on air quality in office and healthcare settings. The effects of air quality on infection rates among patients and staff are reported more frequently, and the psychological, cognitive, behavioral, psychosocial, and social effects of air quality are reported less frequently in studies related to healthcare settings. Unlike studies in healthcare setting, the scope of the studies in office setting is broader on the effects of air quality, and report findings on physiological, psychological, cognitive, behavioral, psychosocial, and social effects.

SBS studies are well-done in both office and healthcare settings, with fewer studies in healthcare settings. These studies cover most issues related to stress. However, cognitive and social effects of SBS remain less studied in both settings. Since most SBS studies are well designed, the findings in either setting are generally valid.

Over all, then, the effects of indoor environment have been studied more in office settings than in healthcare settings. More research is needed on the psychosocial and social effects of noise in healthcare settings. Regarding the effects of lighting, it is necessary to study more diverse patient populations in healthcare settings. Studies on the psychological, cognitive, psychosocial, and social effects of ambient temperature and air quality in healthcare settings are almost absent. There is a need for more research on air quality in office settings. Though most studies on SBS are well-done, there are few studies in healthcare settings.

9. PROBLEMS AND PROSPECTS OF SHARING EVIDENCE

Earlier in this paper, it was suggested that any direct, causal relationship between the physical environment and stress may be difficult to establish. However, because sufficient evidence exists which links the physical environment and stress, the role of the physical must not be ignored. However, gaps in the knowledge are obvious, and these gaps remain uneven in the environmental research of healthcare and office settings. As a result, the possibility for knowledge sharing between these two research areas should be carefully considered.

In order to use any environmental research findings either in healthcare or in office settings, it is necessary to note that the physical environment may affect individual and workplace needs differently in these settings. Within most hospitals and/or healthcare settings, there is a general need for more efficient and effective communications among various groups of hospital workers for they provide services to patients with diverse needs, and any breech in communications due to indoor environmental variables in hospitals can be severe.

Power relations among hospital worker groups are also more asymmetric than they are among office workers. For example, there is a significant power gap between physicians and nurses in hospitals. Hospitals can be very stressful environments for average nurses because they are expected to implement, without question, the physicians' directions for patient treatment. This is despite the fact that nurses often have more direct contacts with patients and have a greater knowledge and understanding of patient's immediate needs than do physicians. Being already under significant stress due to lower job status, nurses are likely to be more affected by indoor environmental design flaws than physicians, who not only have more power but also spend less time with patients in hospital wards. This is not to suggest that significant power gaps between different groups of office workers do not exist. However, any status gap is likely to be less pervasive and less stressful in offices than it is in hospitals – an issue that may need further investigation.

Probably the most important thing to note is that patients, maybe their families as well, in healthcare settings are very different from healthy individuals in office settings. A sense of depersonalization, a lack of control over one's body, and a complete reliance on healthcare professionals make patients already vulnerable to stress. As a result, any negative effects of indoor environmental elements on patients and their families can only be more intense. In addition, each patient group may have different environmental needs – an issue that has received very little attention in environmental design research. That is because it is difficult to conduct a controlled study in hospital settings involving any

particular patient group. Such studies often require a very close collaboration among environmental designers and researchers, hospital staff, and patients and their families.

Another important fact to consider is that healthcare settings are generally more complex physical settings than most office settings. With inpatient, outpatient, and diagnostic areas, healthcare settings can have a vast array of spaces, each potentially having multiple zones that vary in their need for space, access, environmental control, and technology. Additionally, most healthcare settings need to function efficiently and effectively 24 hours a day, every day of the year. While maintenance of an office setting can be done after normal working hours, maintenance of a healthcare setting must be done during working hours when people are present. Furthermore, since most healthcare settings functions 24 hours a day, issues related to circadian rhythm become important. The same environmental problem in a healthcare setting may have different implications not only for different zones but also for different times of the day in the same functional zone. Some of these problems may exist in some office settings as well, but the complexity of environmental problems in offices is not the same as it is in healthcare settings.

Despite the differences between healthcare and office settings, there are many reasons why environmental studies done in one setting can be useful in the other. First, findings in one setting may suggest new research opportunities for the other setting. For example, studies in office settings have suggested that people who work in noisy places may become insensitive to social cues or that the effects of noise on task performance may vary depending on the nature and complexity of tasks. Similar research studies in healthcare settings may be extremely useful in helping healthcare staff improve their social life and work performance.

It might also be beneficial if researchers working in healthcare and office settings take note of each other's work. In this way, each group can learn more about the limitations of their own research design and methodology. While each group deals with different contexts, research studies done in one setting may provide some guidance to similar studies in the other setting. For example, natural experiments have been more common in the study of the effects of air quality or natural light on patients in healthcare settings. In contrast, researchers of office settings have relied more on self-reported data to study the effects of the same elements on office workers. These study designs have their own advantages and disadvantages. Familiarity with each other's work may help researchers in both settings to do better research in general.

Finally, every day new materials and methods are being devised to reduce the negative effects of noise, lighting, ambient temperature, and air quality within buildings. Healthcare settings are always risky places to test these new materials and methods primarily because of immediate health concerns. For these new materials and methods, office settings can be used as test sites. Findings in office settings can

potentially help to guide the next innovations and/or improvement in the study and design of healthcare settings.

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