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The Physiological and Psychological Effects of Windows, Daylight, and View at Home

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Abstract
Following the discovery that intrinsically photoreceptive retinal ganglion cells are responsible for entraining circadian rhythms to patterns of light and dark, and furthermore that those cells are most sensitive to short-wavelength optical radiation, considerable attention has focused on the possibility of using daylight to achieve a healthy lit environment. Daylight is rich in that area of the spectrum, and bright at the times of day that seem most important to these processes. The science has moved rapidly in the ten years since the last substantive reviews of the state of the art on the health and well-being effects of daylight and windows, making it time for a renewed examination of the literature. Moreover, there has been scant attention paid to the role of daylight in residential buildings. This presentation will give a brief overview of three processes by which windows and skylights in homes might influence health and well-being: light dose, view, and architectural aesthetics. Windows and skylights also influence long-term sustainability, through which they indirectly will affect health and well-being of present and future generations. The presentation will conclude with suggested research directions to bring together these strands, as will be necessary for the derivation of practical recommendations.

Introduction

The international lighting community has been reinvigorated by the discovery that retinal photoreceptors are not limited to the rods and cones that mediate vision, and by mounting evidence that exposure to regular rhythms of light and dark is important to the maintenance of health and well-being (Commission Internationale de l'Eclairage (CIE), 2004). New collaborations between fundamental science, engineering, and architecture, are emerging both to study these phenomena and to develop ways in which to apply the findings. Considerable attention has focused on the possibility of using daylight to achieve a healthy lit environment.

Three substantive reviews of the state of the art were completed nearly ten years ago: Farley and Veitch (2001) and Boyce, Hunter, and Howlett (2003) focused on daylight and windows in workplaces, and the CIE (2004) focused on developing general scientific principles for healthy light exposure based on the evidence available through 2003. Given the burgeoning literature, it is time for a renewed examination of the literature as a whole. Moreover, there has been scant attention paid to the role of daylight in residential buildings.

This presentation will give a brief overview of what is known at present concerning three processes by which windows and skylights might influence health and well-being: as contributors to overall daily light exposure; as the means to provide a view of outdoors; and, as influences on room appraisals. The indirect effects of windows on long-term well-being through their role in creating sustainable buildings are a separate consideration. Finally, the presentation will conclude with suggested research directions that might aid in resolving the application issues in the specific domain of domestic buildings.

Well-Being

The definition of “health” adopted here is that of the World Health Organization (World Health Organization (WHO), 1948): “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” To be certain, this establishes a high bar for success. In the case of lighting, this means using light and lighting to create good conditions, and not only eliminating the bad.

Light Dose

The 2004 CIE report concluded with five principles of healthy lighting:

1. The daily light dose received by people in Western [i.e., industrialized] countries might be too low.
2. Healthy light is inextricably linked to healthy darkness.

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3. Light for biological action should be rich in the regions of the spectrum to which the nonvisual system is most sensitive.
4. The important consideration in determining light dose is the light received at the eye, both directly from the light source and reflected off surrounding surfaces.
5. The timing of light exposure influences the effects of the dose.

In the seven years since the CIE report, evidence favouring an increase in light exposure has mounted. aan het Rot, Benkelfat, Boivin, and Young (2007) found that mildly seasonal, but healthy, young women who had been nutritionally deprived of tryptophan (a precursor of serotonin, a neurotransmitter important to experiencing positive mood states) experienced a drop in mood when exposed to dim light (10 lx), but not when exposed to bright light (3000 lx). That is, the bright light blocked the mood decline that would otherwise have happened during tryptophan depletion. It is early days to understand how light exposure influences neural pathways beyond the pineal gland and melatonin regulation, but this study offers a clue to an important physiological mechanism.

Self-reported mood is not the only outcome to benefit from bright light exposure. A naturalistic study related light exposures assessed using the Actiwatch system to the quality of social interactions (aan het Rot, Moskowitz, & Young, 2008). Participants wore the Actiwatch for 20 days, during which time they completed a questionnaire following each social interaction that lasted more than five minutes. The social interactions that followed periods exposed to more than 1000 lx at the wrist were reported as being less quarrelsome and more agreeable than those following lower light levels, after controlling for season, day, time and location.

Principle 3 concerns the spectral power distribution of light exposures, and led the CIE committee to suggest that increased use of daylight might be an effective means to deliver light with strong contributions in the short wavelength region of the optical spectrum (CIE, 2004). However, it remains unclear exactly what dose to recommend.

Two experiments in workplaces have suggested that workday exposures to relatively high quantities of short-wavelength radiation delivered using a 17,000 K fluorescent lamp can improve daytime alertness and night-time sleep quality (Mills, Tomkins, & Schlangen, 2007; Viola, James, Schlangen, & Dijk, 2008).

Only very recently have measurement devices become available to enable naturalistic assessments of the spectral properties of daily light exposures (Gordijn, Giménez, & Beersma, 2009; Hubalek, Zöschg, & Schierz, 2006) and few studies have appeared in the literature. Hubalek, Brink, and Schierz (2010) found that office workers' light exposure patterns differed markedly between workdays and days at home; some of the days at home showed very low light exposures. Days with higher total light exposures were followed by nights of higher-quality sleep. The daily patterns for this sample were quite different from previously reported data for security guards in the same country (Koller, Kundi, Stidl, Zidek, & Haider, 1993), suggesting that occupation influences light exposure patterns even for daytime workers.

Relatively little research has focused on the relative importance of time of day for light exposures to exert benefits on well-being (as opposed to time-of-day effects for circadian regulation). We might assume that for most people, residential light exposures occur primarily early and late in the day, before and after work (Hubalek, et al., 2010). If the timing of the light exposure is important to its effects on well-being, we need more targeted research to determine the best location for this exposure. Exposure timing is certainly important for circadian regulation (Gillette & Tischkau, 1999), but the optimal pattern of light exposure for other biological or psychological processes is not yet known.

Most of the research on which the CIE principles were based comes from either laboratory studies or from studies in real or simulated work settings (CIE, 2004). Almost none has focused on light exposure at home, although a few studies have taken naturalistic samples that combined home and work or community light exposures. Clearly, we need more information before making architectural recommendations for residential design based on delivering any particular light dose.

Views of Outdoors

Windows provide daylight in buildings, and may also provide a view of outdoors. The character of the view is important to human well-being. Extensive research in environmental psychology has established that

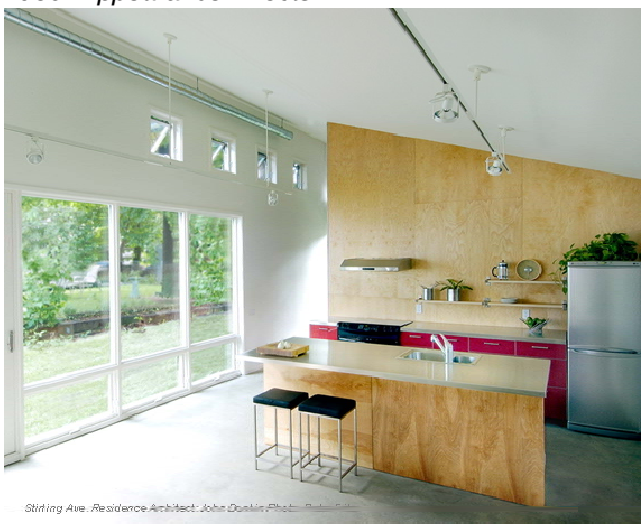
access to nature, both through a view and through immersion in natural settings, is beneficial. Hospital patients with a view of green spaces, as opposed to those with a view of a blank brick wall, recovered more quickly from surgery and required less post-operative pain medication (Ulrich, 1984). This benefit is not simply associated with the possibility of a higher light exposure from a more exposed façade: University students viewing images of natural scenes showed faster physiological recovery from a prior stressful experience than those who viewed built environment scenes (Hartig, Mang, & Evans, 1991).

The precise mechanism for these benefits is not known (Hartig, 2008). One possibility, known as Attention Restoration Theory, is that natural environments have characteristics that promote exploration rather than directed attention, thereby allowing directed attention abilities time to replenish (Berman, Jonides, & Kaplan, 2008). This explanation can account for the cognitive benefits of nature exposure, but less clearly explains the psychophysiological results.

Aesthetic judgements that promote positive affect might also be implicated. One study of office workers separated the quality of the view from its content, and examined the effects of both on measures of office impressions (appraisals of the appearance of the space), physical and psychological discomfort and night-time sleep quality using path analysis to examine an underlying structural model (Ariës, Veitch, & Newsham, 2010). Views that had been independently judged to be more attractive were associated with reduced discomfort and, through the discomfort effect, with better sleep quality. Nature views had contradictory results with both direct and indirect effects on discomfort. There was a direct effect in which nature views increased discomfort, but a simultaneous indirect path through which nature views improved office impressions and contributed to the reduced discomfort associated with better office impressions.

Clearly, not every residential building can have a view of nature, and probably not every building can have an attractive view (natural or not); however, to the extent that these are available, site-specific choices of window placement and sizing can reveal views that will contribute to the inhabitants' well-being.

Indoor Appearance Effects



Given the strong general preferences for windows and daylight (Collins, 1976; Farley & Veitch, 2001; Veitch & Gifford, 1996), surprisingly little research exists concerning the effects of windows on the appearance of interiors in any building type.

A window would be expected to create a rougher boundary to the space than would a smooth wall (see figure at left); boundary roughness contributes to judged spaciousness, which is seen as a desirable characteristic of spaces (Stamps & Krishnan, 2006). This finding is consistent with Butler and Biner's (1990) finding that skylights are desirable to increase feelings of spaciousness. In general, there is a preference for relatively high vertical luminances, at least in offices where the question has been investigated (Cetegen, Veitch, & Newsham, 2008; Newsham, Richardson, Blanchet, & Veitch, 2005); a daylit space will in general be more likely to deliver a higher luminance than a non-daylit space.

Despite these desirable dimensions of windows and skylights, they are not uniformly desirable. Rather, preferences for both windows and skylights are a function of the setting (Butler & Biner, 1989, 1990). These two studies did find that windows and skylights are desirable in living rooms, dining rooms, and family rooms, and less so in bathrooms.

Inhabiting a home that is judged to be more attractive may be considered a psychological good in itself. Some might consider residential aesthetics to be desirable upgrades but not essential to the provision of shelter. In this context consider the evidence that higher residential quality (as judged by objective scales of the physical environment) benefits both physical and psychological health (Evans, Wells, Chan, & Saltzman, 2000; Gifford & Lacombe, 2006).

Building Science

The preceding might seem to argue that the psychological and physical health benefits of windows should result in dramatically increased provision for fenestration in residences. That is not the intent of the argument. Determining the requirements for windows in homes will also require consideration of other dimensions and the factoring in of building science issues. For example, windows are restricted along facades in relation to the proximity of neighbouring buildings as a protection against fire spread (e.g., Canadian Commission on Building and Fire Codes (CCBFC), 2010). The window that provides either daylight or a view of outdoors also has thermal effects on building conditions and building energy use, which need to be held in balance. Even when we know more about the physical and psychological benefits of daylight and view in residences, the application of that information will require interdisciplinary discussion to achieve the proper balance between the various considerations.

Towards A Research Agenda for Residential Daylighting

Little formal attention appears to have been paid to the role of windows in the domestic setting. Some of the research questions raised by the foregoing review overlap with larger issues in lighting research; others are more specific to residences. The list presented here is a first step towards considering the issues.

1. We need more detail concerning the necessary light dose for well-being, in terms of
    - Timing
    - Intensity
    - Spectrum
    - Duration
    - Pattern

Ecological studies of light exposure, designed carefully to include a variety of indicators of well-being and using a variety of measurement methods, would aid in this quest.

2. We need to know more about the balance between providing a healthy light dose to the eye, and preventing problems of discomfort or disability glare.

3. We need to know more about how light affects various population groups, bearing in mind that the physiological and psychological needs of various age groups and other subpopulations are different.

4. Further consideration of the experiences of discomfort and disability associated with high luminance (glare) in residences would help to set the balance between light exposure and glare control. At home one generally has greater freedom of movement to avoid aversive conditions than one has at work, where the majority of discomfort research has been conducted. It might be that glare tolerance is higher at home than at work, or that people use behavioural means to control glare (e.g., moving seats; adjusting shades) that are not available at work.

5. We need to know more about the role of home and views from home in providing restorative environments; little of the research has focused on that setting.

6. Focused research on the effects of windows and skylights on spatial appraisal in residences would help to provide guidance on the aesthetic benefits they might provide.

7. In considering the possibility of making more use of windows to provide daylight for light exposure and to reduce electric demands for lighting, research should also consider the implications for privacy, seeking a balance between increased light exposure indoors against (unwanted) exposure to view from outdoors.

Conclusions

Worldwide, pressure is mounting to develop sustainable buildings — that is, buildings that meet the needs of today without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). It may be that increasing our use of daylight as a light source in all settings is an important means to contribute to our own well-being while reducing our

dependency on electric lighting. Residential daylighting strategies may need to be modified, or new strategies developed, to enable our homes to make their fair contributions to this endeavour. Before we take that step, we first need to improve our understanding of the several dimensions in which windows, daylight, and view affect the occupants of a home.

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