Daylight and View through Residential Windows: Effects on Well-being

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ABSTRACT

The discovery of intrinsically photoreceptive retinal ganglion cells (ipRGCs) in 2001 was a great leap forward in photobiology, and ignited strong interest in the possibility of using light exposure to improve health and well-being. CIE in 2004 promulgated five "principles of healthy lighting", and proposed that these principles should lead to a renewed emphasis on architectural daylighting because daylight is rich in the short wavelengths and bright at the times of day that seem most important to circadian regulation. 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. There has never been a thorough review that focused on residential windows, so our review has focused on that application. This conference paper will briefly report on the review and summarize the research questions that we think are most urgently in need of answers.

Keywords: Windows, daylight, view, health, well-being, intrinsically photoreceptive retinal ganglion cell, visual performance, spatial appearance, comfort, residence, home

1. INTRODUCTION

The general public, as well as the community of people interested in lighting, have never been more interested in knowing how to use light to benefit well-being. Advances in photobiology have shown that the retina is more complex than previously thought, with separate pathways carrying information about light for vision and other processes. Circadian regulation research showed first that intrinsically photoreceptive retinal ganglion cells (ipRGCs) 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. This led the Commission Internationale de l'Eclairage (CIE) in 2004 to promulgate five "principles of healthy lighting" [CIE 2004/2009],which included the suggestion that these principles should lead to a renewed emphasis on architectural daylighting.

The last substantive reviews of the state of the art on the health and well-being effects of daylight and windows were a decade ago[Boyce et al. 2003; CIE 2004/2009], making it time for a renewed examination of the literature. We recently reviewed this literature with a focus on residential buildings [Veitch and Galasiu 2012], concluding with a research agenda of questions that remain unanswered. This conference paper focuses on research related to residential settings; for conclusions that could apply to any building type, please consult the full report, or see Veitch, Christoffersen, and Galasiu [2013, April]. The paper concludes with a consideration of how this research might be integrated with other building sciences to deliver integrated housing solutions.

2. RESEARCH SUMMARY

Fundamental processses are the organizing principle for the report. Processes in this instance are explanatory mechanisms for physiological and psychological events occurring in the individual in response to daylight and view exposed through residentialwindows. These are visual processes: visual performance, spatial appearance, discomfort, stress and restoration; and non-visual processes: circadian regulation, mood and alertness; and finally, skin-mediated processes: infra-red and ultraviolet radiation responses. This conference paper omits the full references available in the report.

Most lighting and daylighting research does not take place in homes. Laboratory studies have shown that visual performance is well predicted by task size, contrast, and retinal illuminance, and moderated by age. This has led to recommendations for appropriate light levels. Nonetheless, surveys of residential lighting conditions consistently show levels that are much lower than recommended practice (e.g., median illuminance at seating location 120 lx, versus IES recommendation of 300 lx [Bakker et al. 2004]). This is in part because, although daylight is available, closed curtains and shades keep levels low even by day. It is not clear what factors prevent people from making better use of daylight to assist in visual performance.

Both the light and the view through windows contribute to feelings of spaciousness and to favourable assessments of room appearance. However, there are some room types where the desire for privacy outweighs desire for a spacious appearance, and there may be some cultures where preventing outsiders from having a view in is more important than providing a view out.

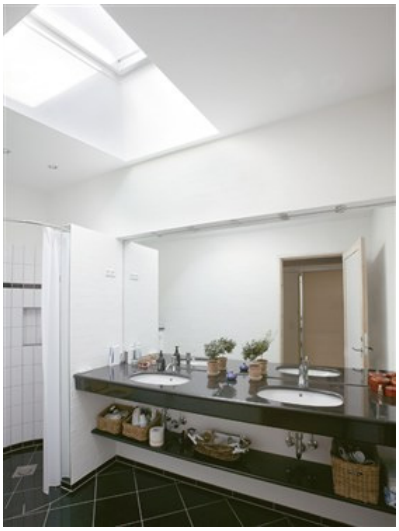

Figure 1 – A nature view aids restoration from daily stresses (left), but in some settings we prefer the daylight and privacy of a skylight (right). Photos © VELUX A/S. Used by permission.

Direct sunlight provides light and warmth, which some people believe to be therapeutic. Conversely, direct sunlight and a bright sky can both cause visual discomfort, particularly for the elderly; however, there are no models to predict this discomfort in residences. We know very little about the reasons for shades to be drawn at home, and have no guidance to solve the paradox created by the fact that the windows that provide the greatest feeling of spaciousness also lead to the worst discomfort, both visual and thermal (the latter both in the form of heat gain on a sunny day and radiant cooling on a dark winter day).

Bright light exposure by day and periods of darkness at night are known to support good circadian rhythm regulation. Although some estimates have appeared in the literature, it

is not known yet exactly what light or dark dose each day is best. Moreover, field surveys show that individuals do not consistently self-select good conditions; some do not sit in the brightest spaces by day, and others keep blinds and curtains closed even when glare is not likely to be a problem. We do not yet know how best to promote good light (and dark) hygiene practices.

Figure 2 – Good blinds provide darkness at night, but control glare by day. Photos © VELUX A/S. Used by permission.

Several lines of research show that increased light exposure by day can promote a pleasant mood and feelings of alertness, independent of circadian regulation. Other evidence shows that people of low socio-economic status (SES) are at risk for lower well-being than those with high SES, and that poor housing quality is a contributor. Lack of access to daylight could be one factor in this complex equation.

Windows also deliver ventilation, moderate thermal conditions, and influence building energy use. Nonetheless, studies concerning the effects of windows on thermal comfort in homes, particularly for those who are housebound, is entirely absent. There are also no studies that integrate thermal and visual comfort associated with windows.

3. RESEARCH AGENDA

In this section, we summarize the research agenda developed out of the literature review.

Table 1 – Summary of knowledge and research questions, for residential application

Process	State of the Science	Open Questions
Visual performance	• Residential light levels are generally lower than illuminance recommendations for vision, especially for the elderly. • Findings based on only a few surveys in a limited range of cities.	• Why do people choose low levels in their homes? Are the levels acceptable, even if they are lower than recommended practice? Would better daylight (including appropriate means to prevent glare) improve visual performance?
Spatial Appearance	• There is good evidence that living rooms look more spacious, beautiful, and inviting with windows, especially with larger and more transparent windows. • Privacy leads to smaller and	• Where in the dwelling do people want windows or skylights? How large and where should they be located in the space? What factors other than light and view influence these preferences? For instance: privacy; wall areas for

Process	State of the Science	Open Questions
	fewer windows desired in bathrooms. • Cultural factors and room functions influence window preferences. • Greenish tints for glazing are undesirable. • However, there is too little data on specific dimensions or window features to create design guidelines based on spatial appearance models.	other functions (display, storage); hobbies and tasks requiring darkness; and, prevention of veiling luminances on key surfaces could all influence these choices. • Does the view influence the space appearance, and in turn is this an influence on desired window size and other characteristics?
Discomfort	• Anecdotal evidence says that discomfort is not the only reason for shades to be drawn. • Glazing conditions that are perceived as giving the best spatial appearance also give the worst discomfort. • All discomfort prediction models area based on offices, and have limitations, for nonuniform light sources and in the failure to integrate daylight or non-lighting variables.	• What predicts the lighting conditions at home that cause visual discomfort? • What are the interactive effects of visual and thermal sensations relating to comfort and discomfort? • When do residents close their shading devices? Why do they close them? What effect does this have on the light dose received? What are the consequences for electric lighting energy use?
Stress and restoration	• Strong research designs show that a view of nature facilitates restoration from stressful experiences, with emotional, physiological, and cognitive benefits. The results have been consistent for hospital, classroom, and residential settings and across age groups.	• What is the restorative value of view attractiveness separately from its nature content? • Do people increase their light exposure because they look outside more when the view is attractive or of nature?
Circadian regulation	• Higher daily light dose (for most people, best delivered earlier in the day) contributes to better sleep quality. • Exposure to gradual dawning (through window or through simulation) can improve sleep quality ratings and morning alertness. • There is no standard definition of a healthy circadian rhythm (or range of patterns) in terms of the amplitude, duration, or timing of melatonin secretion nor of sleep/wake patterns. This	• Where in the dwelling do people spend their time when at home? • Which populations spend the most time at home and therefore might benefit most from obtaining light exposure through design features? • In any given room type, what proportion of the time is spent in various orientations and at varying distances in relation to the façade? Do people orient themselves towards the façade? • How can we promote healthy light hygiene? For example, are

Process	State of the Science	Open Questions
	makes it difficult to establish the practical significance of statistically significant results.	there design features that could encourage healthy light exposure?
Mood and alertness	• Ecological studies of light exposure show high variability during days spent at home, apparently a function of self-selected activities. • Higher light exposure is associated with better mood and more cooperative social behaviour. • Replication studies are needed.	• Would higher daytime light exposures at home improve mood and social behaviours in families? • Could the absence of daylight be a risk factor for well-being that is more likely in homes of those with lower SES? Could better daylighting in homes be a way to improve housing quality?
Thermal sensation	• There is a total absence of research on the interactive or combined effects of thermal sensation and visual sensations associated with windows, daylight, and view in homes.	• Some populations are likely to be more sensitive to these tradeoffs than others. One might expect adaptability to be lower in the elderly and those who are ill or housebound.
Ultra-violet radiation	• UV exposure for vitamin D synthesis requires time outdoors. There is no meaningful possibility of increasing healthful UV through windows or daylight.	• Home designs that facilitate time spent outdoors in sunny weather, particularly for those whose mobility is limited, would contribute to healthy vitamin D status.

4. CONCLUSIONS

Although many details remain to be learned, it is clear that windows contribute to health and well-being both by delivering light to the eyes and providing a means to see the view. The optimal design of healthful housing should include appropriately sized and oriented openings to deliver both. These openings will need to be modifiable to exclude direct sun, when that is wanted, to provide privacy, and to exlude light at night.

Precisely what size the openings need to be remains to be determined. A method for predicting light exposures for circadian regulation has been developed, based on simulations of residences in several European locations [Mardaljevic et al. 2011]. The simulation tools are reasonably well-developed and robust; however, predictions of light exposure for circadian regulation depend on many assumptions about the dose-response relationship, timing, and spectral effects; these are weak because the fundamental photobiology is still under development. Applying better information about the necessary dose to this method could provide predictions about daylight availability for circadian regulation in a wider range of geographical locations for which climate data are available.

Predictions about possible daylight exposures in homes require validation based on field data: We need to know how real people live in their houses. What evidence there is, suggests that their light exposure at home falls short of the ideal – even though we are not yet certain exactly what that ideal level ought to be. With a better understanding of how people use window shades to prevent discomfort and to provide privacy, and with stronger evidence about necessary light doses, we would be better able to develop integrated recommendations for daylighting in residences and better guidance for residents concerning how to live well in them.

Providing daylight and view through residential windows are necessary but not sufficient conditions for good home design. Windows also provide ventilation and contribute to thermal conditions in homes, and influence energy use for lighting, heating, and cooling. Few studies have attempted to simultaneously predict light exposure, thermal conditions, and energy use in a space, and none appear to have done so for residences in any climate. This balance is necessary in order to meet local requirements for building energy use in new construction. Meeting future sustainability targets will also require attention to retrofit and renovation strategies, which might differ from those for new buildings; over 70% of dwellings in the EU are over 20 years old [Nemry and Uihlein 2008].

Practical guidance for the architectural community, including those who develop standards and codes, will require an integration of these several research domains. The result will be pleasant, comfortable homes that conserve energy in their local climates.

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