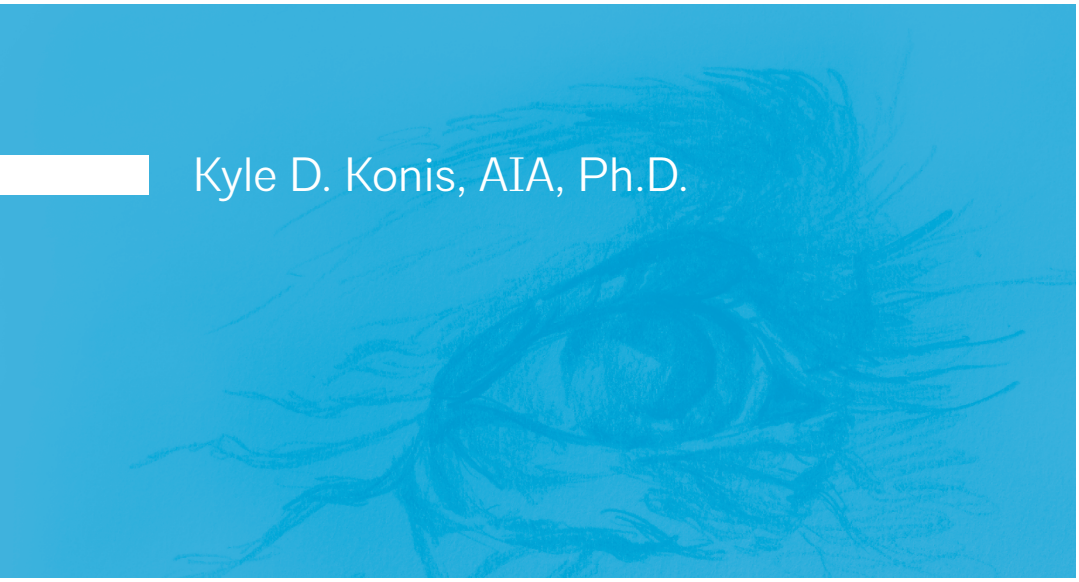
DAYLIGHT & DEMENTIA CARE

Daylight design performance criteria for dementia care facilities



Kyle D. Konis, AIA, Ph.D.

Acknowledgment

The project team would like to acknowledge Silverado, the American Institute of Architecture Upjohn Research Program, and the USC Davis School of Gerontology for supporting this work.

Author

Kyle D. Konis, AIA, Ph.D.

University of Southern California
School of Architecture
Watt Hall, Suite 204
Los Angeles, CA 90089, USA

This manuscript was submitted in conjunction with a national professional conference, "The Value of Design: Design & Health," hosted in Washington, D.C., April 22–24, 2014, by the American Institute of Architects Foundation, the American Institute of Architects, and the Association of Collegiate Schools of Architecture. Conference staff have edited manuscripts for clarity and style. This project was made possible in part by a grant from the National Endowment for the Arts.

Introduction

The number of people age 65 and older with Alzheimer's Disease and Related Dementia (ADRD) is estimated to reach 7.1 million by 2025—a 40 percent increase from the 5 million age 65 and older currently affected (Alzheimer's Association, 2013). There is no known cure for Alzheimer's disease, and decades of research and development of drug treatments to help with cognitive and behavioral symptoms has produced drugs with limited benefits and often-serious side effects. All Alzheimer's patients eventually require full-time care at home, in the community, or in long-term care facilities. Among these three care environments, the severity of cognitive and behavioral symptoms increases most rapidly when patients are in long-term care facilities. This paper presents ongoing research initiated through a multi-disciplinary collaboration between the USC Department of Architecture, the USC Davis School of Gerontology, and Silverado[a], a large dementia-care provider in Southern California. The long-term objective of this research is to establish empirical daylighting requirements and performance criteria tailored specifically to assess and inform the design and operation of dementia-care facilities. A parallel objective is to develop simulation-based workflows, case study design projects and novel architectural light-delivery systems demonstrating the successful implementation of these criteria.

The utilization of daylight as the primary indoor light source for circadian stimulus is an attractive alternative to electrical lighting sources due to its spectrum[b], intensity, general availability, and potential to be introduced into spaces via windows and skylights to minimize restrictions on the movement and activities of residents. Apertures delivering daylight provide additional co-benefits via environmental cues (e.g. views to the outdoors signaling time of day, orientation, outdoor weather conditions, and other activities) that can increase interest and stimulation as well as aid in maintaining spatial orientation and way finding. However, studies examining the effects of interior daylight exposure on managing sleep, behavior, cognition, or mood disturbances associated with dementia are extremely limited (Forbes et al., 2009). Moreover, reliance on daylight introduces a range of additional design issues that must be considered, including availability, timing, distribution, avoidance of glare, and control of solar overheating. There are currently no minimum requirements for daylight access in dementia-care facilities (or assisted living facilities in general), nor refined criteria to guide optimal use of daylight to improve health and well-being of ADRD patients through design. Current lighting criteria for buildings (even buildings designed for aging adults) are focused on improving lighting conditions for visual tasks and electrical lighting-energy reduction goals, not biological needs.

[a] http://www.silveradocare.com/

[b] The circadian system is maximally sensitive to short-wavelength ("blue") light, with a peak spectral sensitivity at around 460 nm. This peak spectral sensitivity matches closely with the peak spectral power of common daylight illuminants (solar beam radiation, clear blue, and diffuse skies) (Andersen et al., 2012).

The following section presents a summarized review of existing research relating lighting and daylighting exposure to the heath and well-being of aging adults, in particular those with ADRD. Gaps in existing knowledge are identified and used as a basis to outline a research agenda for addressing critical knowledge gaps and to map a path for translating emerging empirical findings into guidance to improve the architectural design and operation of dementia-care facilities. The paper concludes by discussing a field study informed from this research, which has been designed to examine and quantify the effects of indoor daylight access on multiple Alzheimer's health and well-being outcome measures at four dementia-care facilities in LA County.

Literature review

LIGHT AS "THERAPY"

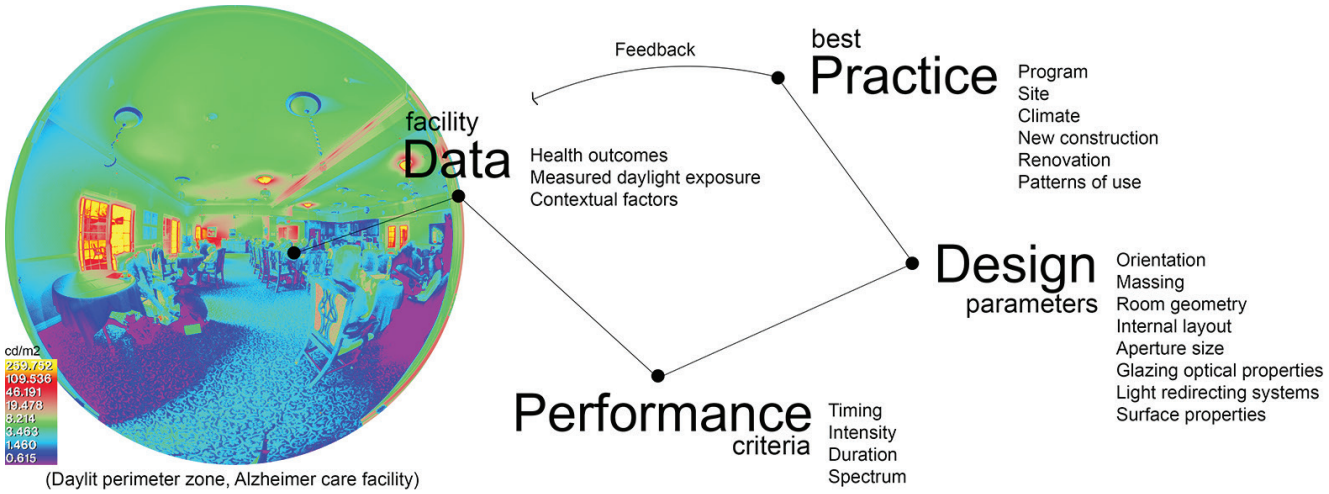
Humans, like all biological life, possess an internal biological clock that regulates daily patterns of activity following the light and dark pattern of the 24-hour solar day. The suprachiasmatic nuclei (SCN) hosts the circadian clock (or circadian system) responsible for orchestrating the daily timing of biological functions, for example, sleep/wake, alertness level, hormone suppression/secretion, and core body temperature. The period of the SCN is slightly greater than 24 hours and relies on light received at the retina to maintain entrainment with the solar day. The action spectrum of light for the circadian system is shifted towards shorter wavelength (~460 nm) "blue" light (Brainard et al., 2001; Thapan et al., 2001) with respect to the visual system, which is maximally sensitive to (~555 nm) "green" light. Consequently, light that may be perceived effective for visual tasks may not be an effective stimulus for circadian entrainment. This has led to the effort to precisely define the term "circadian light" in order to articulate the fundamental differences between responses by the visual and circadian systems to optical radiation (Rea et al., 2010). Further, the aging of the eye and patterns of light exposure affect the sensitivity of the circadian system to light, leading to implications for the intensity and duration of light required. In institutionalized settings, lack of sufficient exposure of the retina to bright, circadian-effective light is considered one of the primary contributors to disruption of the circadian system, with cascading effects of sleep disruption, agitated behavior, depression, and cognitive decline (Day et al. 2000). Exposure to bright light (> 1000 lux at the cornea), typically administered in the morning via electrical lighting, has been shown to be an effective non-pharmacological treatment option for sleep disturbances (Dowling et al., 2005; Hanford and Figueiro, 2013) and for ameliorating behavioral problems (Cohen-Mansfield, 2001; Hanford and Figueiro, 2013) for people with Alzheimer's disease. However, Bright Light Treatment (BLT) presents an array of practical implementation problems for routine use in care settings[c] by restricting the personal movement and activities of residents and has led to reported side effects of irritability, dizziness, and headache when used as a treatment for people with ADRD (Labbate et al., 1994; Terman, 1999; Riemersma-van der Lek et al., 2008).

DAYLIGHTING DESIGN REQUIREMENTS AND PERFORMANCE CRITERIA

Although there have been relatively few rigorous studies examining the impact of long-term exposure to 24-hour light/dark patterns (particularly with daylight as the primary light source) on the health outcomes of ADRD residents, there is a sufficient body of theoretical knowledge (Figueiro, 2008; Figueiro et al., 2008; Andersen et al., 2012) and empirical data (Deschenes et al., 2009; Hanford and Figueiro, 2013) to begin to explore how efforts to orchestrate 24-hour light/dark patterns to improve sleep efficiency and other health factors could be achieved through design at a range of scales to optimize circadian-effective stimulus from daylight while balancing multiple other lighting and environmental objectives.

[c] Using a standing light box is problematic because patients must sit still for the treatment and be supervised so they do not fall asleep or wander away.

FIGURE 1: Framework diagram showing potential for emergent scientific knowledge to be translated into practical information to guide the design, renovation, and operation of care facilities.



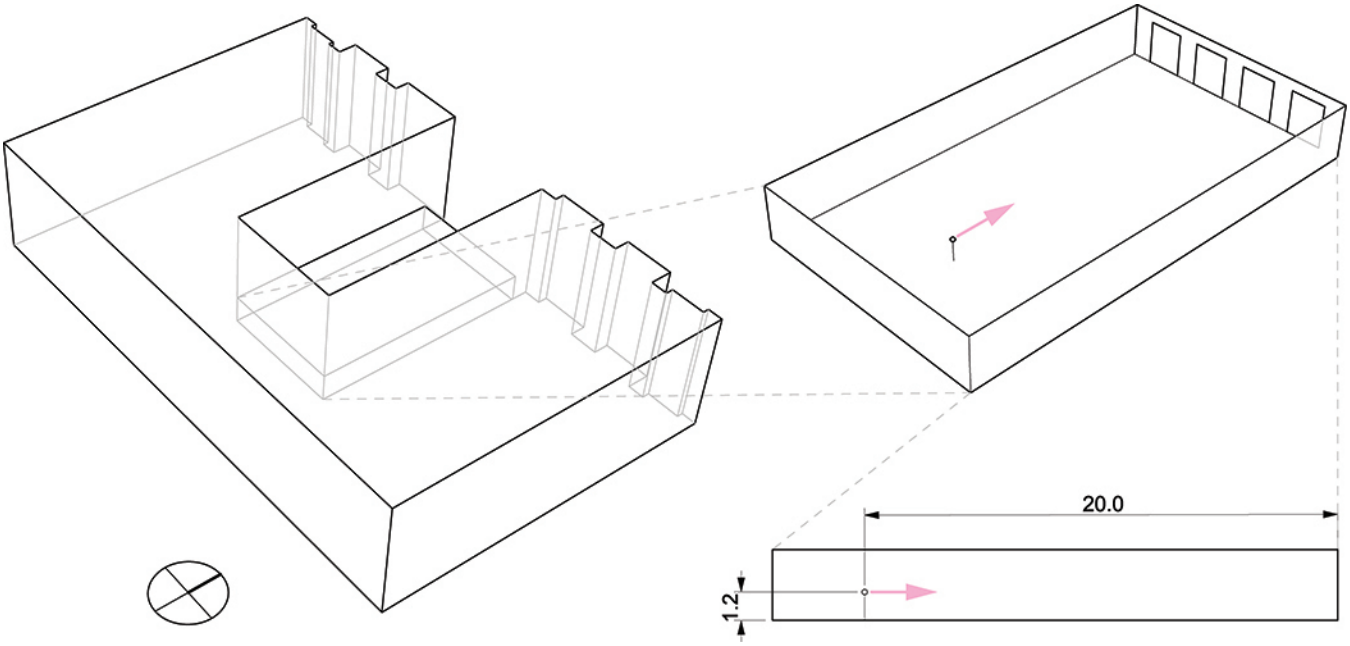
CONNECTIONS BETWEEN DESIGN AND HEALTH: A PERFORMANCE-BASED DESIGN FRAMEWORK

The objective of this design framework is to demonstrate the positive impact of design interventions (principally through the optimized use of daylight as a circadian stimulus) on human health, supported and refined through a coordinated feedback loop incorporating health outcome data from facilities in use. For ADRD residents with a disrupted circadian phase, the principle goal is to resynchronize the circadian phase with the solar day. For long-term exposure, the goal is to maintain entrainment. The important note here is that light "therapy" from short "doses" of light and long-term maintenance of circadian entrainment via orchestrated exposure to patterns of light/dark are fundamentally different concepts that lead to different implications for design.

The above framework diagram (Figure 1) illustrates a feedback loop linking facility design to daylighting performance criteria for the timing, intensity, duration, and spectrum of circadian-effective light. A pilot field study, summarized in the following section, seeks to validate theoretical assumptions for these variables (e.g. > 2000 lux for 2 hours after waking) on short-term resident health outcomes. Given appropriate assumptions for the ideal timing, intensity, duration, and spectrum of daylight for stimulation of the circadian system, the design problem is then how best to manage the multiple architectural parameters (e.g. aperture size, room orientation, fenestration properties) to achieve the desired daylighting conditions while maintaining control over glare and solar overheating, as well as the additional design constraints unique to each project site, context and program.

As a first step, the photobiology-based model developed by Andersen et al. (2012) and the mathematical process developed by Pechacek et al. (2008) to calculate the "circadian efficacy" of various light sources will be applied in annual climate-based daylight simulations following the simulation approach described by Mardaljevic et al. (2013) to quantify the circadian potential of existing spaces. Figure 2 illustrates a preliminary application of the approach to determine the vertical daylight exposure at the eye for a seated position in a large interior gathering space located at one of the four facilities selected for the field study. The basic room geometry,

FIGURE 2: Example interior daylit space and single observation point used to model daylight exposure at the eye. The figure illustrates the challenges of estimating a precise exposure due to changes in view-point location and direction throughout the course of the day.



windows, and surrounding urban context are modeled in the 3-D modeling software Rhinoceros and imported into the lighting simulation engine Radiance where window glazing and material surface optical properties are assigned. An annual climate-based daylighting simulation informed from local weather data is then performed to determine the vertical illuminance at the eye for each hour of the year. At this initial stage of development, the simulation workflow reports photopic lux rather than circadian-equivalent lux, which has yet to be implemented. A visualization of 24-hour patterns of daylight access for the observation point in Figure 2 is presented in Figure 3, aggregated by month for the purpose of exploring seasonal variation in daylight access.

Figure 4 illustrates the approach applied to additional facilities and spaces. The approach will be applied to characterize a selected set of interior spaces (e.g. dining area, public gathering spaces, typical bedroom), within each of the four test sites. Circadian potential (interpreted over daily, seasonal, and annual timescales) will be quantified for each space, and using knowledge of daily patterns of use at each facility (which are orchestrated by facility caregivers), an overall value will be estimated for each facility. In addition to physically monitored daylight levels, the circadian potential for each facility will then be compared against the baseline and outcome data collected from residents participating in the field study (see following section) to examine the hypothesis that residents in spaces with higher circadian potential experience relatively fewer negative health outcomes. The next step in this ongoing research will be to apply this approach to additional care facilities identified through outreach and collaboration with our healthcare partners and to begin to develop practical design best practices. The following step will be to develop a series of case-study daylit spaces exploring how both common and novel daylighting strategies can be refined parametrically in response to multiple daylighting performance objectives and unique site, program, and climate constraints.

Field Study Design

To examine the application of daylight as a stimulus to the circadian system to improve health in dementia-care facilities, a three-month field study in four

FIGURE 3: 24-hour "clock" plot displaying timing, intensity, and duration of photopic lux from annual (8760-hour) climate-based daylighting simulation for single observation point (Figure 2). Each circular increment indicates 100 lux.

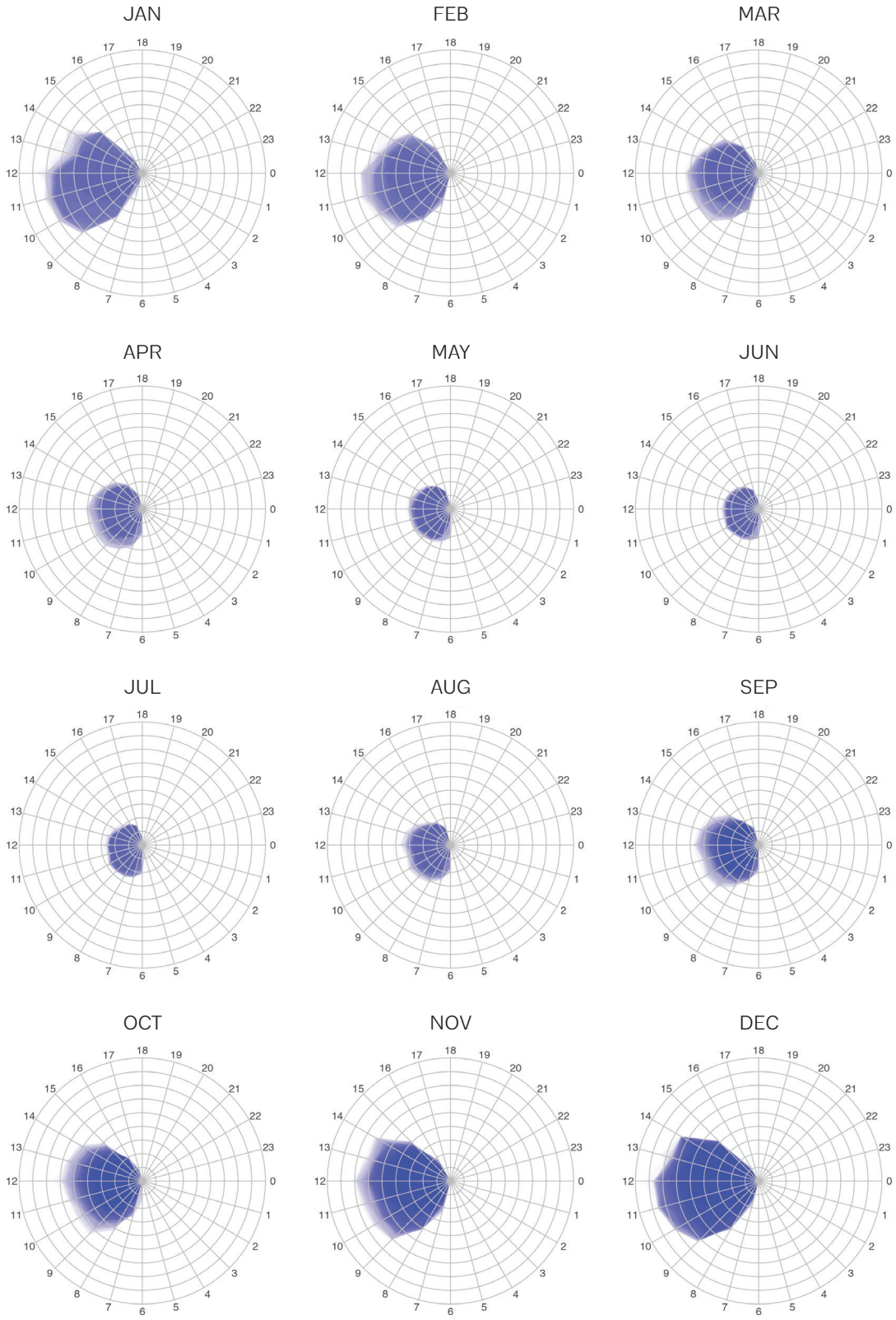
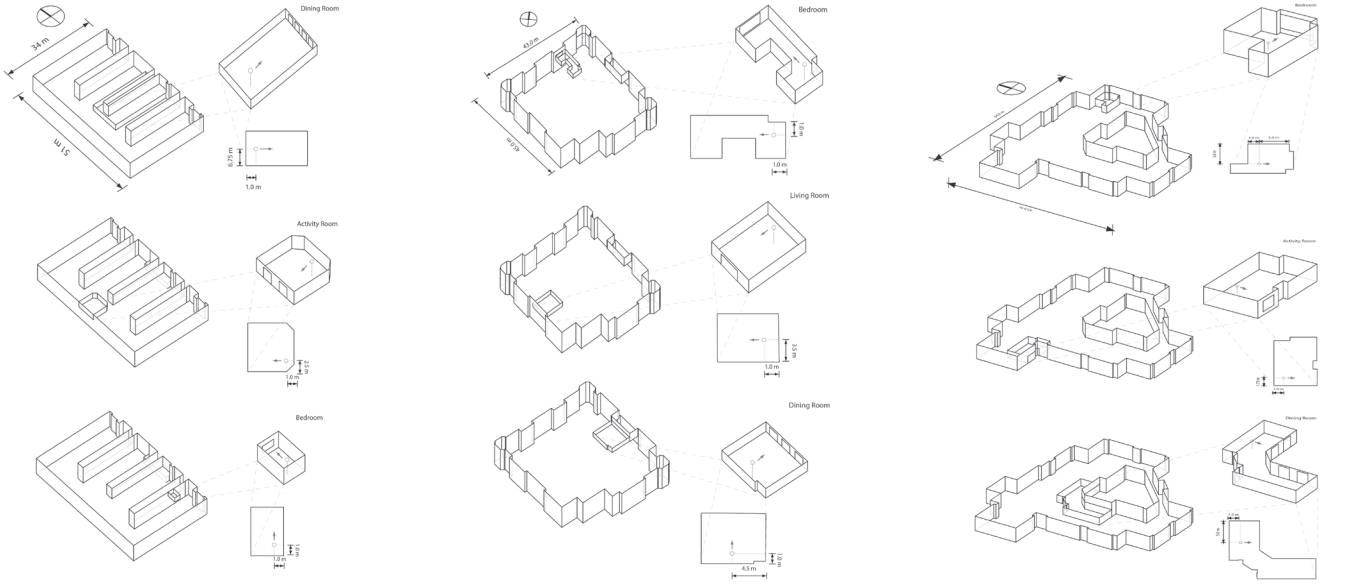


FIGURE 4: Illustration of the room-level approach applied to traditional facilities and spaces.

(Source: Christina Clementi)



dementia-care facilities in Los Angeles County has been designed in partnership with Silverado. Silverado is an assisted-living service provider that delivers care for those with Alzheimer's, dementia, and other memory-impairing diseases. The study is designed to utilize only interior daylight as a stimulus to reflect the practical limitation of many urban facilities to restricted access for residents to the outdoors due to weather, lack of available outdoor spaces that are secure and comfortable for extended time periods, and risks of wandering. A total of four facilities were selected for the pilot field study. At two facilities, an intervention will enlist staff to increase daylight exposure for Alzheimer's residents by taking them to a daylit perimeter room in the morning (9:00 – 11:00 AM) where vertical daylight illuminance at eye level exceeds 2000 lux and where direct sun exposure can be avoided. Patients at the other two facilities will receive the usual care. During the period from 9:00 AM to 11:00 AM each day, the control group will be taken to a similar-sized area indoors without daylight exposure for socialization under typical interior fluorescent-lighting conditions. We hypothesize that depression symptoms and negative behaviors will be reduced and cognitive function will improve after the three-month intervention among participants in the intervention group and that the control group will show no significant change or will decline.

At all facilities, the following patient outcome measures will be taken:

1. **Patient outcomes** (completed at baseline and 3 months). For each of our major outcomes, we will use instruments that are well-validated for use in testing effects of short- to long-term interventions in AD:
    a. Depression: Geriatric depression scale, long form (Yesavage et al., 1983)
    b. Cognitive ability: Alzheimer's Disease Assessment Scale-Cognitive (ADAS-cog), (Rosen et al., 1984)
    c. Behavior: Behavioral Pathology in Alzheimer's Disease Rating Scale (BEHAVE-AD) (Reisberg et al., 1987)
2. **Trial conduct/methods outcomes:**
    a. Facility and staff support and participation: facilitators and obstacles.
    b. Fidelity of light and control intervention: facilitators and obstacles.
    c. Data collection fidelity: patient outcomes and light measures.
    d. Estimates of subject recruitment, consent, and attrition rates: facilitators and obstacles.

e. Estimates (and confidence intervals) for study/trial planning: intervention effect size, variance of outcome measures, within-facility correlation in outcome measures, within-patient correlation in outcome measures (repeated measures).

Outcome measurements will be confined to those who meet the trial inclusion criteria (AD diagnosis, no physical co-morbidities that preclude participation in the daily group intervention). Based on current facility records, we estimate the intervention and control groups will each include approximately 50 Alzheimer's disease participants each (25 patients per facility). Demographic information obtained during the study preparation phase (mean age, type of dementia by diagnosis, depression level, length of time in facility) will be obtained to show that the facilities are comparable. Human Subjects Institutional Review Board (IRB) approval is currently in progress. All analyses will include factors for facility and intervention (nested within facility). Baseline analyses will include descriptors of the study sample (age, gender, race, MMSE) as well as initial levels of the outcome measures (depression, cognition, behavior) and will utilize analysis of variance for continuous data and chi-square methods for categorical data to compare the intervention groups. Three-month outcomes will be compared between intervention groups with analysis of variance (2-level factor for intervention, 4-level factor for facility, with intervention nested within facility).

Conclusion and Next Steps

Theoretical knowledge, expert judgment and emerging findings from photobiology are sufficient to begin to propose 24-hour patterns of light/dark that have the potential to be orchestrated through thoughtful architectural design at a range of scales to improve the health and well-being in dementia-care facilities. However, it is important to develop and refine feedback loops between the assumptions made during design and observed health outcomes of projects in use. This paper described parallel simulation and field-based research efforts currently in progress to examine the relationship between circadian-effective daylight exposure and their possible positive impact on heath outcomes for ADRD patients. The long-term objective of this research is to translate findings into empirically-based environmental lighting metrics for use in the design, renovation, and operation of dementia-care facilities so that they more effectively support the health and well-being of residents. Results from the pilot study are not intended to establish the basis for these metrics. Rather, the proposed pilot is the first step in establishing an appropriate methodology for carrying out additional, much larger studies aimed at translating research findings to specific quantitative guidance that architects can use to shape the built environment to better-support health and well-being. Demonstration of the hypothesized effects will serve as the fundamental first step to continue more refined research to examine specific parameters of daylight treatment (e.g. timing, intensity, duration, spectral quality) and their effects and mechanisms of effects on depression, cognitive function, behavior, and other health outcomes in persons with Alzheimer's disease.

References

Alzheimer's Association. (2013). *Depression and Alzheimer's Disease Fact Sheet*. Retrieved from: http://www.alz.org/alzwa/documents/alzwa_resource_bc_fs_depression.pdf.

Andersen, M., Mardaljevic, J., & Lockley, S.W. (2012). A framework for predicting the non-visual effects of daylight – Part I: photobiology-based model. *Lighting Research and Technology* 2012 44: 37.

Brainard, G. C., Hanifin, J. P., Greeson, J. M., Byrne, B., Glickman, G., Gerner, E., & Rollag, M. D.. Action spectrum for melatonin regulation in humans: Evidence for a novel circadian photoreceptor. *Journal of Neuroscience* 2001; 21: 6405–6412.

Cohen-Mansfield, J. (2001). Nonpharmacologic Interventions for Inappropriate Behaviors in Dementia, A Review, Summary, and Critique *Am J Geriatr Psychiatry* 9:4, Fall 2001.

Day, K., Carreon, D., & Stump, D. (2000). The Therapeutic Design of Environments for People With Dementia A Review of the Empirical Research. The Gerontologist (2000) 40 (4): 397-416.

Deschenes, C., & McCurry, S. M. (2009). Current Treatments for Sleep Disturbances in Individuals With Dementia. Curr Psychiatry Rep. 2009 February ; 11(1): 20–26.

Dowling, G. A., Hubbard, E. M., Mastick, J., Luxenberg, J. S., Burr, R. L., & Van Someren, E. J. W. (2005). Effect of morning bright light treatment for rest–activity disruption in institutionalized patients with severe Alzheimer's disease. Int Psychogeriatr. 2005 June; 17(2): 221–236.

Figueiro, M. G., Saldo, E., Rea, M. S., Kubarek, K., Cunningham, J., & Rea, M. S. (2008). Developing Architectural Lighting Designs to Improve Sleep in Older Adults. The Open Sleep Journal, 2008, 1, 40-51.

Figueiro, M. G. (2008). A proposed 24 hour lighting scheme for older adults. Lighting Res Technol 40 (2008), 153-160.

Forbes, D., Morgan, D. G., Bangma, J., Peacock, S., & Adamson, J. (2009). Light Therapy for Managing Sleep, Behaviour, and Mood Disturbances in Dementia (Review). Copyright 2009 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

Hanford, N., & Figueiro, M. (2013). Light Therapy and Alzheimer's Disease and Related Dementia: Past, Present, and Future. Journal of Alzheimer's Disease 33 (2013) 913–922.

Labbate, L. A., Lafer, B., Thibault, A., & Sachs, G. S. (1994). Side effects induced by bright light treatment for seasonal affective disorder. J Clin Psychiatry 1994; 55:189–191.

Mardaljevic, J., Andersen, M., Roy, N. & Christoffersen, J. (2013). A framework for predicting the non-visual effects of daylight – Part II: The simulation model. Lighting Res. Technol. 2013; 0: 1–19.

Pechacek, C. S., Andersen, M, Lockley, S. W. Preliminary method for prospective analysis of the circadian efficacy of (day) light with applications to healthcare architecture. Leukos 2008; 5: 1–26.

Riemersma-van der Lek, R. F., Swaab, D. F., Tiwsk, J., et al. (2008). Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities: a randomized controlled trial. JAMA 2008;299:2642–2655.

Rea, M. S., et al. Circadian light. Journal of Circadian Rhythms, [S.l.], v. 8, p. Art. 2, feb. 2010. ISSN 1740-3391.

Terman,M,, & Terman, J. S. (1999). Bright light therapy: side effects and benefits across the symptom spectrum. J Clin Psychiatry 1999; 60:799–808.

Thapan, K., Arendt, J., & Skene, D. J. An action spectrum for melatonin suppression: Evidence for a novel non-rod, non-cone photoreceptor system in humans. Journal of Physiology 2001; 535: 261–267.

THE AMERICAN INSTITUTE
OF ARCHITECTS

AIA Foundation

ACSA
ASSOCIATION OF COLLEGIATE
SCHOOLS OF ARCHITECTURE

1735 New York Avenue, NW
Washington, DC 20006-5292
www.aia.org