KEY POINT SUMMARY

OBJECTIVES

The present paper details results of simulations used to determine the percentage of days that individuals lying in bed or sitting upright would receive a CS value needed to promote circadian entrainment, as a function of different window characteristics such as window-to-facade ratios, surface reflectances, and latitudes.

Analysis of circadian stimulus allowed by day lighting in hospital rooms

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Key Concepts/Context

Light is the major synchronizer of circadian rhythms to the 24-hour solar day. Compared to the visual system, the circadian system requires more light to be activated and is more sensitive to short-wavelength light. For those confined indoors, such as patients or residents in care facilities, the lack of access to daylight, or electric lighting providing a comparable amount, spectrum, distribution, duration, and timing, may compromise their human health and well-being. Neither daylight factor nor daylight autonomy fully describe the impact of daylight on health and well-being, because these metrics quantify light only for the visual system. A circadian stimulus (CS) metric has been developed to measure sensitivities of the human circadian system to light (CLA). It can potentially be a useful metric to quantify how much daylight from windows is available to those confined indoors.

Methods

A virtual room was utilized for this study. Measuring 3.0m wide, 6.0m deep, 3.0m high, the size of a typical hospital room in the studied locations was used to analyze various day lighting strategies. The room ceiling, walls, and floor had a thickness of 0.25m. Square windows of variable sizes were centered in the 3.0m wide facade. The double-pane window was 0.05m thick with a visible transmission of 0.75.

In order to estimate CS received at the eye level of a patient sitting upright and facing forward, CS was calculated at points on a vertical plane located at a height of 1.00m above the floor, according to the typical height of a chair. In order to estimate CS received at the eye level of a patient lying in bed, CS was calculated at points on a horizontal plane above the floor, a typical height for a hospital bed. To account for different bed locations in the room, the calculation points were spaced at 0.30m intervals from the window/facade, 0.50m from the side walls, and 1.00 m from the center row.

Two locations in Europe at different latitudes and with different sky conditions were chosen to illustrate the impact of variation of daylight availability: (1) London, UK, at 508 north latitude and with predominantly overcast skies; and (2) Madrid, Spain, at 408 north latitude and with predominantly clear skies. Weather data for both locations are defined by the Energy Plus reference.

Findings

As expected, the CS values are higher in the zone near the facade, gradually decreasing towards the back of the room. Obviously, the larger windows provide higher CS. However, as can be deduced from the results, the window area and resulting CS values are not directly proportional. Rooms with window to-facade ratios of 60% and 80% provide similar CS values; therefore, there is no significant benefit to having a particularly large window. That is to say, windows with an area higher than 40% of the facade allow an evenly distributed CS. Significantly, daylight provided greater CS on the vertical plane compared to the horizontal plane, suggesting an advantage for patients to be sitting rather than lying down for a period in the morning.

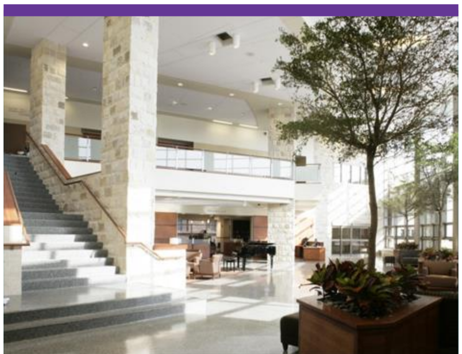
To provide the CS criterion in the entire room, a window-to-facade ratio of at least 40% is needed for a patient lying down and 30% for a patient sitting up.

For the room with low reflectance surfaces in London, a typically overcast location, even a window with an area equal to 80% of the facade is not large enough to provide a CS value of 0.35 in the entire room for a lying patient; however, a window-to-façade ratio of 40% or higher meets the criterion CS for a sitting patient, even in this low-reflectance room.

For Madrid, a location with typically clear skies, a window with an area equal to 10% of the facade is sufficient to obtain a CS value greater than 0.35 at a distance of 2.0m from the facade. This ratio should be increased to 20% if the surfaces of the room have low reflectance. A room with high-reflectance surfaces and a window-to-facade ratio higher than 30% provides a good CS on the entire horizontal plane.

Design Implications

This metric can be used as a guideline to assist architects, engineers, and designers to provide healthy indoor lighting that impacts more than just vision.



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Limitations

The authors noted that it is still not known whether humans adapt to lower levels of light for the circadian system and whether the CS value of 0.35 may be enough to maintain entrainment.

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