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View clarity index: A new metric to evaluate clarity of view through window shades

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A B S T R A C T

Connection to the outdoors through window views has been related to occupant satisfaction. While view quality depends on outdoor scenery, view clarity can be quantified according to fenestration properties and visual conditions. This paper investigates view clarity through window shades (fabrics) used in commercial buildings. A field study with 18 human subjects was conducted to measure view clarity preferences in offices equipped with 14 shading fabrics of different transparency and color. The tests, including subjective and objective responses, were repeated for different sky conditions and viewing distances. The collected data were used to create a view clarity scoring system and fabric rankings. A new metric, the View Clarity Index (VCI), was developed based on averaged normalized scores using all processed data. The results showed that darker fabrics with higher openness generally achieve higher clarity scores. A few exceptions confirmed the complex combined impact of shading optical properties on view clarity. The influences of fabric type, sky conditions and viewing distance were statistically quantified. In most cases, cloudy conditions and longer viewing distances (up to 2.4 m) resulted in higher view clarity; however, the VCI rank order was not affected by these factors. Finally, the results were used to develop a reliable model capable of predicting VCI for any shading fabric, using only the shade openness factor and visible transmittance. The new index, together with glare and energy use considerations, can be used to evaluate the overall performance of shading products, leading to improved indoor environmental design and occupant satisfaction.

1. Introduction

Indoor environmental comfort and the factors that affect it have always been central for the building design and operation community. Given the strong belief that daylighting is beneficial for health [1] and the fact that almost any view to the outdoors is preferred over having no view [2], office spaces are becoming gradually more transparent, utilizing glass facades with larger outdoor views and daylight provision. While the focus of research has been on thermal and visual comfort, view through windows and connection to outdoors is the least investigated aspect related to occupant satisfaction, considering both subjective and objective parameters.

Subjective factors, such as view quality, are generally associated with psychological sciences and mainly include preferred outside scenes. Aries et al. [3] showed that window views rated as "more attractive" can result in reduced glare; however, this effect can be reversed for occupants seated close to unshaded windows. Tuaycharoen and Tregenza [4] also attempted to associate discomfort glare with satisfaction from window views, concluding that the perception of glare was lower for "interesting" scenes. Similar findings, connecting the type of view through the window with perception of glare [5] or even with job stress and well-being [6] or health recovery [7], have been reported.

Objective considerations are more important in urban areas, where there is limited flexibility in choosing the most desired outdoor scenery. Building rating systems [8] offer credits for outdoor views, without elaborating on details. The only quantifiable elements of connection to the outdoors are (i) the amount of view outside, in terms of relative size of openings compared to opaque

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walls, and (ii) the view clarity through windows. For the first, Galasiu and Veitch [1] suggest optimal window sizes of 1.8–2.4 m in height and somewhat wider than taller, although window size will vary for different office settings. On the other hand, view clarity through windows with shading devices has not been studied. The basic concept of view clarity is even abstract, without a clear definition [9]. Aston and Belichambers [10] refer to it as a metric of sense of satisfaction, whereas Boyce [11] defined it as the level of something being "visually distinct and clear". Early studies associated clarity with distinctness of detail [12] or considered the visual clarity of an illuminated scene to be highly correlated with the specific spectral concentration of light sources [13].

The clarity of view through actual windows or glass facades depends on the layers of fenestration (glazing and shading systems) and their optical properties. The glazing visible transmittance, which depends on the type of glass and coating used, also determines the ability to see through the glass. Most modern glazing products have a high visible transmittance to allow more daylight into the space, thus their impact on view clarity is not substantial. In contrast, any type of shading (e.g., venetian blinds, roller shades, draperies and screens) significantly affects the clarity of outside view, since they block part of the window and influence the direct–direct and direct-diffuse light transmission. Venetian blinds allow partial direct outdoor view depending on their shape and rotation angle. Tzempelikos [14] presented a detailed method for calculating the projected outside view for venetian blinds of any shape (flat and curved) as a function of rotation angle, taking into account edge effects and slat thickness. Window shades (fabrics) allow direct outdoor view when they are partially open. However, due to their perforations, they enable some outside view even when fully closed. Although recent studies provide measurements and recommendations for selection of roller shades with respect to glare [15], view clarity through shading fabrics has not been studied.

This paper is the first known attempt to characterize view clarity through window shades (fabrics), commonly used in commercial buildings. A new metric, the View Clarity Index (VCI), was developed based on the preferences of human subjects in a field study, with different sky conditions and distances from the window, using 14 different roller shade products with a wide variety of optical properties. The data collected from 18 participants were used to evaluate scoring distributions and the overall View Clarity Index for every studied case, while a statistical analysis identified the significance of each parameter and validated the reliability of results. Finally, the results were used to develop a semi-empirical model that uses the shade openness factor and visible transmittance (usually provided by manufacturers) to predict view clarity through shading fabrics. The new View Clarity Index, together with glare and energy use considerations, can be used to evaluate the overall performance of shading products, leading to improved indoor environmental design and occupant satisfaction.

2. Experimental methodology

2.1. Test facility

The field study was conducted in two identical, side-by-side test office spaces in West Lafayette, Indiana (Fig. 1a). These spaces are designed with reconfigurable façade systems and are ideal for comparing the relative impact of different technologies (glazing, shading and controls) on indoor environmental conditions, occupant impressions and energy use under real weather conditions. The dimensions of each room are 5 m wide x 5.2 m deep x 3.4 m high, with a glass façade facing south (60% window-to-wall ratio). The reflectivities of interior surfaces are equal to 30% (floor); 50% (walls and dividers); and 70% (ceiling), typical for office spaces. A high performance glazing unit (SB70XL-clear) with a low-e coating was used (*normal visible transmittance* = 65%). For the purpose of this study, each room was reconfigured with the addition of two vertical panels (Fig. 1b) in order to form six total partitioned areas. Each partitioned area would host a different shade product. The view section in each partition was 1.5 m wide by 2.1 m high, starting from 0.7 m from the floor. The study included objective observations; for that reason, six visual targets with modified Landolt-C charts (Appendix A) were installed on a vertical fence outside the rooms, at a distance of 4.5 m from the windows (Fig. 1c). Each chart was on the direct line of sight from each partitioned section. The general outdoor view is open and unobstructed, with visible green areas and a nearby street with traffic.

2.2. Selected shades and optical properties

The shade optical properties potentially affecting the view clarity results were identified before selecting fabrics for testing. These are the shade openness factor, visible transmittance and visible reflectance, as defined by ASHRAE [16].

- The fabric openness factor (*OF*) refers to the "open" or "see-through" percentage of the shading fabric. It is also an indicator of weave density and direct light transmission.
- The total amount of transmitted light (part of it falling on the eye) affects the viewing ability and therefore the clarity of view. The shade visible transmittance (T_v) defines the percentage of visible light transmitted through the fabric and is indirectly related to its color and openness factor. Light-colored fabrics have higher T_v than darker fabrics of the same *OF* due to additional direct-diffuse light transmission.
- The fabric color, related to interior visible reflectance (R_v), is associated with contrast and potentially affects the view clarity as well.

These properties generally depend on wavelength and incidence angle. Collins et al. [17] designed a modified integrated sphere to

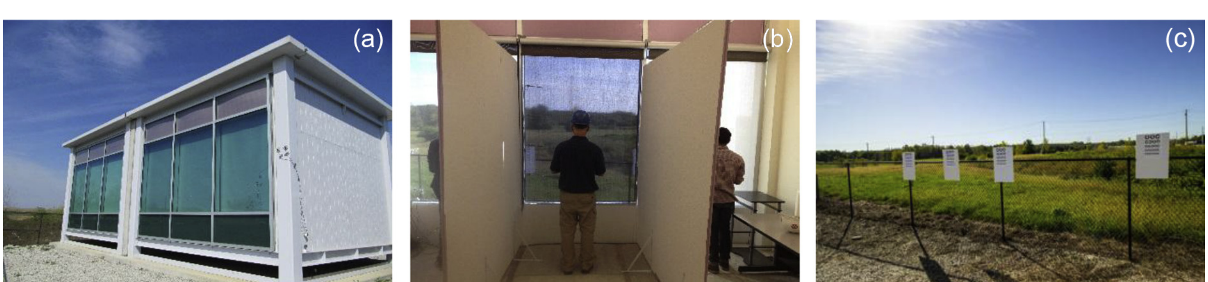

Fig. 1. (a) Exterior view of test offices (left), (b) interior partitioning (middle) and (c) Landolt C boards installed outside (right).