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Adaptive glazing technologies: Balancing the benefits of outdoor views in healthcare environments

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ABSTRACT

Fully-glazed facades are increasingly common in contemporary buildings. They are further desired for hospital settings where greater connection to outside views is believed to contribute to patients' health and wellbeing. In hot-arid climates, such a design attribute may contribute to excessive solar gain and consequent energy demand. Intelligent glazing technologies provide a potential solution for this with their capacity to autonomously change their optical/thermal properties in response to varying outdoor conditions. Although critical for regulating energy use, in conditions of excessive solar gain, the change of the window colour from clear to fully tinted might obstruct clear views to outside.

This study explores an approach to integrate intelligent glazing and shading devices in order to improve energy performance of fully-glazed buildings while allowing the window to remain more hours in a clearer state. To test this, seven intelligent glazing materials were identified and modelled interchangeably with a set of unobstructive shading devices. A typical hospital waiting area located in the outskirts of Cairo, Egypt with a southern orientation was investigated using EnergyPlus. Annual lighting and cooling loads were computed and compared to determine the combinations that yielded higher energy savings. The number of hours that each glazing spent in the different states was then calculated and compared. The integration of horizontal shadings contributed to additional energy savings while playing a role in improving visibility to outside by allowing the window to remain in a clearer state for an extended time without adversely impacting indoor visual comfort. Further research is warranted to explore alternate shading options, in addition to the implications of other climatic conditions, orientations and building types.

1. Introduction

Waiting is an integral part of a hospital visit where patient experience can be significantly affected. Prolonged waiting times may induce feelings of annoyance, anger and stress, therefore impacting patients' overall satisfaction with their care (Arneill & Devlin, 2002; Becker & Douglass, 2008). In situations where it is difficult to shorten waiting times, supporting a better waiting experience, by paying attention to design aspects of the surrounding physical environment, may play a complementary role in ameliorating such conditions (Nanda et al., 2012). A growing body of research attests that the healthcare physical environment can affect patient satisfaction and well-being and may have positive impacts on a variety of health-related outcomes such as stress and mood (Huisman et al., 2012; Ulrich et al., 2008; Ulrich et al., 2010). This is increasingly accepted for environmental features such as connection to the outside world, particularly nature and therapeutic landscaping (Ulrich et al., 2008).

Having a view to nature for patients is a prominent attribute for developing a supportive and restorative healthcare environment (Burnard & Kutnar, 2015). It serves as a source of distraction of one's focus from his/her own status, triggering positive emotions to counter the potential tensions that are generally associated with illness and being in a hospital (Dijkstra, 2009; Raanaas et al., 2012). Outcomes related to reduced boredom, anxiety (Becker & Douglass, 2008; Pati & Nanda, 2011), stress, perception of pain, analgesic use and length of stay, among others (Vincent et al., 2010; Ulrich et al., 2010), have been linked with a view to the outside and its associated natural lighting. Previous studies point further to patients' preference for healthcare settings that feature increased views to natural elements (Ulrich et al., 2008). One step towards facilitating this connection is to increase window size. In a recent study conducted by Jiang et al. (2016) to investigate preferable window sizes in general healthcare waiting areas,

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the finding pointed to a significant preference toward environments that provide floor-to-ceiling views to the outside. Maximizing outdoor views in such ways allow for greater spatial continuity with the outside environment while facilitating unobstructed views and securing abundant amount of daylighting. Promoting this connection is even more important in harsh weather conditions where people may be forced to remain indoors (Raanaas et al., 2012).

In hot-arid climate regions such as Cairo, Egypt, where harsh desert environment is dominant, increasing window size may adversely affect visual and thermal performance of the building. Excessive penetration of direct sunlight and solar radiation may elevate glare levels, therefore inhibiting occupants' visual comfort (Lee and DiBartolomeo, 2002), in addition to increasing the cooling demand due to overheating (Shikder et al., 2010). For a better understanding of the solar intensity in such regions, Sherif et al. (2013) conducted a study exploring lighting performance for a typical intensive care unit room (5.75 × 4.00 × 3.00 m) located in the city of Cairo. Using a typical clear glazing material in the southern façade, a Window-to-Wall Ratio (WWR) of 8% with no shading protection was adequate for providing acceptable levels of natural lighting while minimizing glare. Although a small window size, larger WWRs failed to meet such acceptable levels as the percentage of over-lit areas drastically increased. The implementation of shading devices, such as horizontal sun breakers, expanded the acceptable WWR to 24%. The greatest performance was observed when external solar screen was implemented which allowed for using relatively larger window sizes, however this remained limited to a maximum WWR of 48%. Increasing window size further would require therefore integration of other solar control techniques if visual and thermal comfort is to be maintained in such harsh climatic conditions.

Sabry et al. (2014) studied further a set of different shading devices with the aim of balancing the performance of daylighting, glare, and energy demand. Simulations were carried on a typical residential living room located in the city of Jeddah, Saudi Arabia with WWR of 16% (a region also characterized by hot arid climate). Once more, a solar screen, featuring horizontal slats, achieved the lowest energy use for the south façade (up to 25% in comparison with a non-screened window) while retaining acceptable daylighting and glare levels. Using solar screens appears to enhance both energy performance and lighting conditions. However, with larger WWR, a typical solar screen may obstruct clear views to outside, therefore hindering its potential wellness benefits. Fig. 1 demonstrates examples of a traditional solar screen called "Mashrabeya" found generally in middle-eastern conventional premises and another contemporary perforated metal screen where blurred vision to the outdoor view can be noted.

In parallel, intelligent or adaptive glazing technologies (AGTs), as referred to by Baetens et al. (2010), are other emerging solar control techniques that carry promising potentials to satisfy visual and thermal comfort within buildings. Depending on their type, AGTs have the capacity to dynamically change their optical and thermal properties (e.g. colour, state of matter) in response to variations in one or more of the parameters that govern their behaviour, such as thermal load, surface temperature and sunlight levels (Favoino et al., 2015; Kamalisarvestani et al., 2013). These changes allow the window to block excessive penetration of unnecessary amount of light and solar radiation (Alzoubi & Al-Zoubi, 2010) by switching its properties gradually from a clear to dark/tinted state, thus contributing to both environmental comfort and reducing the building's energy demand (Casini, 2014; Kamalisarvestani et al., 2013).

Casini (2014) and Jin and Overend (2016) reported on the availability of a wide range of modern intelligent glazing options such as Electrochromic, Gasochromic, Thermochromic, Photovoltaic Integrated Glazing, Liquid Crystal Devices, Spectrally Selective Solar Control Devices, and Suspended-Particle Devices. These products, although similar in operation by using a self-dimming approach, have a varying final performance based on their material technical specifications such as overall heat transfer coefficient (U-value), visible transmittance (Tv), and solar heat gain coefficient (SHGC). Other contributing factors include the switching range between clear and dark states and the available, selective, parameters that govern their operation (Casini, 2014).

Despite the AGTs promising contribution to indoor building performance, their extreme change of state, from clear to fully dark, in response to excessive heat gain, may again hinder clear views to the outside as noted in the thermochromic window example presented in Fig. 2 (Kamalisarvestani et al., 2013). Such change of window colour may dissatisfy occupants further (Wang et al., 2016) as they may perceive the space to be gloomy as noted by Li et al. (2015) in their study of users' acceptability of the application of EC (electrochromic) windows in comparison to traditional low-e glasses.

Furthermore, some types of AGTs may not be able to completely block direct sun and its subsequent glare effects (Lee and DiBartolomeo, 2002; Li et al., 2015) unless meeting specific conditions. For instance, in order for EC windows to effectively neutralize glare effects resulting from direct sun, their light transmission values were proposed by Piccolo and Simone (2015) to be as low as 0.1%. A situation in which the window may retain this heavily tinted state for a large portion of the day when located in hot climate regions. In those circumstances, occupants might experience further thermal discomfort as a consequence of the increased temperature of the internal glass pane of the glazing (Piccolo et al., 2018).

Combining shading devices with AGTs is therefore recommended by Lee and Tavil (2007) who observed considerable improvements in the

Mashrabeya, Bayt Al-Suhaymi, Cairo Egypt. Source: Sadek, October 2010.

Perforated solar screen, Melbourne School of Design, Australia, Source: Sadek, June 2017.

Fig. 1. Examples of indoor and outdoor view through typical solar screen devices.