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Understanding architectural and social-psychological influences on occupant behaviour in commercial buildings

Astrid Roetzel[1] and Chien-fei Chen[2]
[1] *Deakin University, Geelong, Australia*
astrid.roetzel@deakin.edu.au
[2] *University of Tennessee, Knoxville, USA*
cchen26@utk.edu

Abstract: The aim of this paper is to advance the understanding of social-psychological and architectural parameters influencing occupant behaviour and resulting operational energy consumption in office settings. Existing knowledge on occupant behavior is reviewed from an architectural and social-psychological perspective. The identified parameters are visually mapped using the framework of Integral Sustainable Design (ISD). Conclusions are drawn concerning the interrelationship and interaction of parameters and the direction of future interdisciplinary research.

Keywords: Occupant behaviour, office architecture, group norms, energy consumption

1. Introduction

Both residential and commercial buildings consume about 60% of world electricity, therefore the building sector is the largest producer of global greenhouse gas (GHS) emissions (UNEP 2016). On the other hand, buildings offer the greatest potential for reducing significant GHG emission in both developed and developing countries. Yet, the vast majority of energy studies (e.g., in engineering fields) focus on technological fixes for improving energy efficiency rather than human-centered energy behavioral analysis and environmental changes (Sovacool, 2014).

In addition to that, the majority of existing studies on occupant behaviour focuses on occupants' interactions with single building technologies or controls, not with the architectural experience of a building as a whole; and very little knowledge is currently available on how the architectural design of a building predefines human behaviour. Ching (1996) proposes three orders that, when mutually reinforcing and contributing to the singular nature of the whole, constitute a work of architecture, which has more to offer to people than the sum of its physical or technological parts. These are, the physical (form and space, solids and voids, interior and exterior), the perceptual (sensory perception and recognition of the physical elements by experiencing them sequentially in time) and the conceptual (comprehension of the ordered or disordered relationships among a building's elements and systems,

and responding to the meanings they invoke). These three orders are consciously and subconsciously interpreted by occupants and are likely to influence their responses to and actions in buildings.

While recent policy makers have emphasized technological innovations and/or tighter environmental regulations as necessary preconditions for improving energy efficiency, a growing number of social scientists have recently argued nudging energy behaviors that could influence energy efficiency and have a potential impact on grand goals such as reducing GHG emissions (Dietz, et al., 2009). Non-price nudge such as normative feedback can significantly influence energy savings (Goldstein, Cialdini and Griskevicius, 2008) and mounting evidences show that behavioral changes could be just as effective as technological changes (Karatasou, et al. 2014). Therefore, more attention needs to be paid to social-psychological or behavioral factors that could influence energy efficiency (e.g., Abrahamse & Steg, 2009; Dietz et al., 2009). The current literature on individual-level energy saving such as social-psychological factors, however, mainly focuses on households or private contexts. Studies on energy saving behavior in the organizations or public domains and their social-psychological drivers are rarely investigated (Chen & Knight, 2014; Lo et al., 2012). Regarding building design and behavioral modeling, human influence and interactions need to be considered by thoroughly conceptualizing occupants' psychological factors relating to decision-making processes. These decision processes tend to be complex due to the diverse characteristics of occupants (e.g., habits or culture) and other structural factors (e.g., organizational policy) beyond building design and technology. This paper reviews the currently available literature from a multidisciplinary viewpoint, and then uses DeKay's framework of Integral Sustainable Design (DeKay and Bennett 2011) to map the common ground and the interrelationship between the disciplines.

2. Literature review

2.1. Architectural factors

DeDear and Brager (1998) suggested a differentiation between air-conditioned and naturally ventilated buildings for thermal comfort assessment, because the presence of openable windows in naturally ventilated buildings increased levels of perceived control. With regard to lighting control systems the ease of use nature of the task, the number of persons in the room and the distance from windows, lighting concepts (Galasiu and Veitch 2006, Reinhard and Voss 2003), location of the light switch (Bordass et al 1993), age, degree of fatigue and cultural background, the atmosphere of the room regarding the interior design (Galasiu and Veitch 2006), and the external daylight conditions at the arrival at the office (Moore et al 2003) were identified as influential parameters. Inkarorjit (2005) investigated reasons for why people open and close blinds in offices, and observed relationships with the brightness of the workspace surfaces and the perceived spatiousness of the room. Boubekri and Boyer (1992), suggested psychological implications of blind opening, such as cheering up the atmosphere in a room by increasing the level daylight and or sunlight. The nature, placement, accessibility and effectiveness of such controls predefines their use by occupants. E.g. controls which are hidden, complicated to understand, not easily accessible or likely to interrupt colleagues will be interpreted by occupants as less inviting to operate and could thus decrease the perceived level of control. Kwok and Rajkovich (2010) citing Norberg-Schulz referred to this as "switch-rich" design.

Spatial layout of the floor plan arrangement of a building is another architectural parameter which influences and predefines the use of a building. Leaman and Bordass (2010) identified workgroup size, spatial flexibility, and building depth as key variables influencing productivity in buildings. These

parameters are architecturally expressed in the spatial organisation, i.e. the spatial relationships between spaces. Ching (1996) differentiates between centralised, linear, radial, clustered or grid organisation, each suggesting a different nature of the relationship and hierarchies between spaces to occupants. These relationships may impact occupant presence, as well as usage patterns.

Kwok and Rajkovich (2010) citing Norberg-Schulz discuss the importance of transitional spaces as an opportunity for experiencing thermal delight and energy savings. They define transitional spaces as those which are neither clearly indoors nor outdoors. This implies that the relationship between indoors and outdoors is one of communication rather than separation, and thus influences the use of the space by occupants.

The facade defines the relationship between the interior and the exterior environment. This is particularly evident in the presence and fuctionality of windows. Air exchange rates can multiply according to window opening type, opening angle as well as size and placement within the façade (Richter et al 2003). Tsangrassoulis et al (1997) highlighted the potential implications of different activated shading devices on discharge coefficients for windows and resulting ventilation effectiveness. Herkel et al (2008) found that size and placement of windows had a significant impact on occupant's window opening behaviour. Yun et al (2008) found that night ventilation depends on façade design and perception of security. These physical properties have perceptual and conceptual implications which can affect occupants interaction with the building envelope consciously as well as subconsciously.

Another important parameter influencing the design as well as the subsequent use of a building is the immediate context of the site and the neighbourhood. Geros et al (2005) investigated the heat island effect as an influence on air temperatures, wind speed and direction and thus as an indirect impact on natural ventilation effectiveness. Inkarorjit (2005) identified visual privacy and security and visual contact with the outside environment as influential parameters on blind operation.

With regard to night ventilation, the size, protection and accessibility of windows together with the perceived security in the neighbourhood predefines their potential for night ventilation (Roetzel et al 2010). Galasiu and Veitch (2006) observed a dependency of the likelihood of shading opening from the quality of view. View, task, sunlight and atmosphere seem to be more important for visual comfort than external and internal illumination (Galasiu and Veitch 2006). With regard to window size, occupant satisfaction increases with window size, but decreases with the number of mullions (Galasiu and Veitch 2006). Preferred window size was also found to be dependent on the view content (Ne'eman 1970). When a view provides attractive features like open space or greenery, bigger windows are preferred. For a monotonous view like a close building façade or sky without a skyline, the preferred window size is smaller, compared to complex views (Inui 1980). The preferred size and placement of windows also varies dependent on the location of occupants in the room and their view angles (Ne'eman 1970). Additionally people prefer views including nearby as well as distant elements, to those of limited range (Tuaycharoen and Tregenza 2007). This indicates that the context of the building site can have significant influence on occupant's interaction with the building and its controls.

As argued by Jencks (1973) it is the nature of architecture to "help explain and dramatise certain social meanings". In office architecture the implications of social meaning are little discussed. Leaman and Bordass (2007) introduced the concept of "forgiveness" of occupants towards deficiencies in green as opposed to conventional buildings. They referred to 'green' buildings as those where the design brief required the buildings to achieve lower environmental impact. Deuble and DeDear (2012) identified natural ventilation as one feature of green design. Evans and Mc Coy (1998) investigated the impact of architectural design on human health by linking architectural order to stress. Key architectural design

parameters impacting on stress were clarity or comprehensibility of building elements and form, object's sensory characteristics, the ability to alter the physical environment or regulate exposure to one's surroundings and the potential of design elements to function therapeutically. It can be argued that an architectural design which is perceived as intimidating is less likely to facilitate occupant's interaction with the space and its controls compared to a design which actively empowers occupants to interact with its architecture in a more democratic manner. The design of controls, spatial relationships, building envelope and the site context therefore determine the "personality" of a building, which consequently predefines the behaviour of occupants in it.

2.2. Cultures and group dynamics

In this paper, we have narrowed down the concept of cultures but considered group dynamic as one of the important cultural factors affecting occupant behaviors in commercial buildings. Although there is a growing recent emphasis on the investigation between occupants and building environment interaction, engineering researchers often use advanced sensors to model occupant behaviors to solve building energy issues while ignoring the social-psychological or group factors that determine occupants' acceptance and behaviors. Incorporating the concept of social influence or network factors for energy behavioral interventions is widely documented. For example, social messages, such as reciprocity, appear to be the most effective at gaining occupant compared with foot-in-the-door and direct message methods (Khashe et al., 2016). A study conducted among 24 university buildings found that group level feedback and peer education resulted in a 7% and 4% energy reduction at work, respectively (Carrico and Riemer 2011). Other studies also highlight that group-level feedback may promote a sense of collectiveness and help achieve a desired outcome of pro-environmental behaviors (Truelove, 2010). Recent evidences indicate that the three components in the theory of planned behavior (TPB) (Ajzen, 1991), including attitudes, subjective norms, and perceived behavioral control, significantly influence occupants' energy behaviors at the workplace (Greaves, Zibarras, & Stride, 2013). For example, Greaves et al.'s study determined that the TPB explained 61% of variance in employees' intention to turn off their computers when leaving their desk and 53% of variance in intention to recycle at work (Greaves, Zibarras, & Stride, 2013).

Another important group dynamic factor relating to occupant behavior is called group norms. Norms – culturally shared beliefs about how people behave or how they should behave (Cialdini and Trost, 1998) – are powerful determinants on people's behaviour in many areas (e.g., Aarts and Dijksterhuis, 2003), especially on environmental behaviors (Goldstein, Cialdini, and Griskevicius, 2006). Many social-psychological theories, including the focus theory of normative conduct, the value-belief-norm theory, and the theory of planned behavior propose that norms exert an influence on people's intentions and behaviors relating to energy or pro-environmental issues (Ajzen, 1985; Cialdini et al., 1990). Instead of examining only one type of norm, scholars have distinguished the differences between descriptive norms (prevalence of people's actual behaviors) and injunctive norms (prevalence of how people should behave) (Cialdini et al. 1990) and suggested it is useful to consider both types of norms at the same time (Rivis & Sheeran, 2003). A great number of studies show that group norms influence workplace energy use and environmental behaviors (Andrews and Johnson, 2016; Norton et al., 2015; Yun et al., 2013). For example, Chen and Knight (2014) found that injunctive norms (perception of group members' approval on energy saving) and perceived behavioral control have direct and positive effects on energy conservation intention among Chinese utility company employees. In addition, there are correlations between employees' perceptions of supportive organizational norms and their environmental behaviors (Norton, Zacher, & Ashkanasy, 2014), as well as group norms and more general organizational

citizenship behaviors (Kidwell, Mossholder, & Bennett, 1997). Further, normative feedback and messages focusing on environmental concerns are important in promoting energy conservation and collective behaviors (Lindenberg, & Steg, 2007; Xu, Arpan, Chen, 2015); but the long-term effect is generally unknown. One study recently discovered normative messaging positively influenced the long-term durability of behavioral change (Anderson & Lee, 2016). The long-term effect of energy behavior change in Anderson and Lee's study was twice as prevalent in occupants with high concern for social norms. Besides the individual-level factors, organizational or structural factors are crucial in influencing occupant behaviors in commercial buildings. Specifically, top management support and organizational culture are key determinants in explaining workplace pro-environmental behavior (Tudor, Barr, Gilg, 2008; Young et al., 2015).

3. Conclusions

While the sections above discuss the social-psychological and architectural influences separately, it is evident that both perspectives share a common interest in the perceptual experience and cultural interpretation of the built environment. A theoretical framework that aims to unite these different perspectives into one conversation is Integral Sustainable Design (DeKay and Bennett 2011). ISD aims to integrate qualitative and quantitative perspectives on a given subject. The framework is based on four quadrants, which are represented with dotted lines in figure 1. The upper left quadrant explores individual perception of occupants, the lower left quadrant explores the cultural interpretation of collective individuals, the upper right quadrant explores performance and behaviours and the lower right quadrant considers systems and relationships. Each quadrant is a reminder that any given subject can be investigated from more than one perspective. The simultaneous investigation of multiple perspectives will lead to a more holistic understanding of the topic. In this paper the framework of ISD is used to explore various influences on occupant behaviour and the resulting impact on energy consumption. In this case the two left hand side quadrants are related to the discipline of sociology and psychology, and the right hand side quadrants are related to the discipline of architecture. Influential parameters as identified in the above literature review are mapped into the four quadrants of Integral Sustainable Design, and their relationships illustrated (figure 1).

Figure 1 illustrates strong links between the architectural (right hand quadrants) and socio-psychological (left hand quadrants) parameters. The interrelationships between these parameters and how they can impact on the resulting energy consumption of a building require further research. This research will be inherently *interdisciplinary* in nature. Theories, methodologies, and disciplinary insights derived from *social science, architecture, and engineering* will be required to identify effective strategies for lowering energy use. For example, engineers or computer scientists often attempt to define and model occupant behavioural patterns in buildings in relation to overall building energy use. However, the "real-life" measured building energy use is often different than the previously modelled building energy use because the modelling assumptions originally made did not account for social and psychological factors that may indirectly affect occupant behaviours. In contrast, in the social science disciplines, the importance of social behavioural and economic factors affecting energy use has been gradually recognized; however, whereas the commonly used self-reported survey and interview methodologies typically address social, psychological, and economical issues, these have not been used in conjunction with accurate energy usage and feedback for behavioural change in real-time or in a cumulative manner through building technology. As discussed earlier, design based on social factors is

an important area when examining occupant behaviours in buildings. Occupants' interactions (and expected interactions) with buildings may change dependent on the types of design or architectural strategies implemented in a given building. Further research is required to help architects and designers to better understand the interface between the occupants and buildings based on observed behaviours and social factors that may not have been previously considered. Blending disciplinary insights and methodologies from each of these disciplines will provide a more holistic understanding of energy consumption and occupant behaviour.

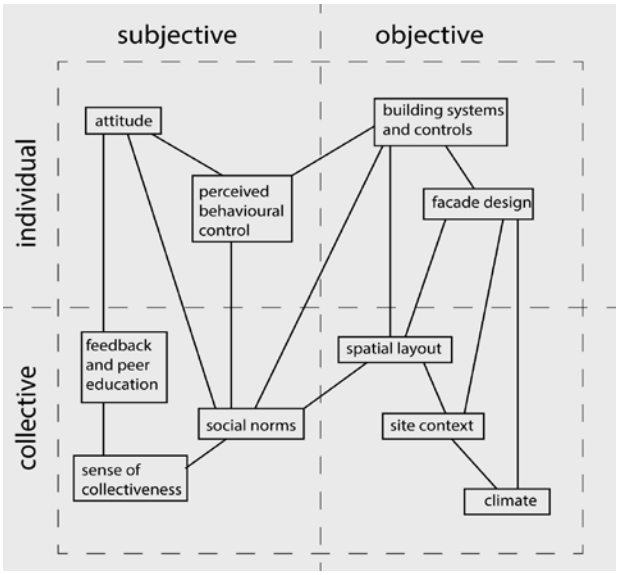

Figure 1: architectural and social-psychological parameters influencing occupant behaviour mapped into the four quadrants of Integral Sustainable Design.

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