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Green occupants for green buildings: The missing link?

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ABSTRACT

Green buildings, often defined as those featuring natural ventilation capabilities, i.e. low-energy or free-running buildings, are now at the forefront of building research and climate change mitigation scenarios. This paper follows the results of recent post-occupancy evaluation (POE) surveys within two academic office buildings located in sub-tropical Sydney, Australia. Supplemented with an environmental attitudes questionnaire, based upon the New Ecological Paradigm [1]), it was found that occupant satisfaction levels on the POE were positively associated with environmental beliefs. Occupants with higher levels of environmental concern were more forgiving of their building, particularly those featuring aspects of green design, such as natural ventilation through operable windows. Despite their criticisms of the building's indoor environmental quality, the 'green' occupants were prepared to overlook and forgive less-than-ideal conditions more so than their 'brown' (non-green) counterparts. These results support the hypothesis that pro-environmental attitudes are closely associated with the stronger 'forgiveness factor' often observed in green buildings, but the question of causality remains moot.

1. Introduction

The built environment contributes greatly to global energy use and greenhouse gas emissions [2]. Fossil fuel energy used directly, or, as electricity to power equipment and condition the air (including heating and cooling) within commercial buildings is by far one of the largest source of emissions in the built environment. Australian commercial buildings account for an estimated 27% of the total greenhouse gas (GHG) emissions within the buildings sector [3,4]. In energy terms, space heating, ventilation and air-conditioning combined represent the largest end-use in commercial buildings, accounting for almost two-thirds (61.2%) of total energy use; the other major end user is lighting (18.6%) and general uses (19.2%) [4].

Contemporaneous concerns over global warming and escalating fossil fuel prices have rapidly emerged into public consciousness. Over the last few years the world has witnessed a momentous change as governments, economies and businesses prepare for a carbon constrained future. Today, architects strive towards ambitious designs which often stretch the ability of building service engineers to provide robust, low-energy solutions [5–9]. With present attempts at mitigating global warming, the buildings sector offers the greatest potential for cost-effective reductions in GHG emissions through the application of both technical and non-technical measures to existing building stock and new construction [2,10].

1.1. Adaptive thermal comfort

Current practices in office buildings typically provide static thermal environments for all occupants using centralised heating, ventilation and air-conditioning (HVAC) technology. However, many adaptive comfort studies (e.g. [11,12]) have called for greater indoor environmental variability, either through user adjustments to operable windows, shade devices, etc., or automated controls shifting HVAC set-points in sync with weather and seasonal variations outdoors. A shift towards greater indoor climatic variability is integral to many sustainable building design solutions. Green buildings (also referred to as green-intent buildings) by definition, aim to reduce their environmental impact by using less energy in both their construction and operation. Thus, buildings featuring natural ventilation capabilities are typically defined nowadays as green buildings. Building users will often employ a wide range of passive cooling strategies and adaptive opportunities [13] available to them to adjust their own comfort conditions to suit their needs.

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It is widely believed that occupants prefer a high degree of adaptive opportunities [13], as can be provided within naturally ventilated (NV) buildings as opposed to centrally controlled air-conditioned (AC) designs. Many studies have found occupants are more favorably disposed to green buildings than their conventional energy-intensive predecessors [14–16]. Within their extensive database of post-occupancy evaluation (POE) studies, Leaman and Bordass [16] observed that occupant satisfaction scores for green buildings tend to be higher than those in conventional AC buildings. But despite occupants preferring greater adaptive opportunities, they do not necessarily *expect* the thermal excursions that sometimes occur in NV buildings, especially during heatwaves. Occupants are often prepared to "forgive" such conditions if they possess a modicum of personal environmental control [17–20].

1.2. Post-occupancy evaluation (POE) and the forgiveness factor

The POE has become an important tool for the improvement of building design and operations [21–23]. However, with clients often broadening their interests to include indoor environments, occupant health and productivity, gaps were often found between client and design expectations for a specific performance level [24]. Faced with the challenge of reducing building and energy costs to accommodate the expansion of its building industry, the UK's Building Use Studies (BUS) launched the PROBE project, which consisted of a series of POE studies for a wide range of non-domestic buildings [24]. This project helped develop a standardised POE method; accumulating a wide range of studies around the world into a BUS database against which future building POE studies could be benchmarked [25].

Recent POE studies from the UK [16] and USA [14,15] suggest that occupants of green buildings tend to forgive minor discomforts provided they can exercise a modicum of personal indoor environmental control. Coined by BUS, the 'forgiveness factor' [16] is an attempt at quantifying how occupants extend their comfort zone by overlooking inadequacies of their thermal environment [26,27]. Illustrated in Eq. (1) below, this index is derived by dividing 'comfort overall' scores on the BUS questionnaire by the average of the indoor environmental quality (IEQ) variables; overall temperature in summer (TempS) and winter (TempW), overall ventilation/air in summer (AirS) and winter (AirW), overall noise (Noise) and overall lighting (Light). All variables are rated along 7-point Likert scales ranging from 1 (unsatisfactory) to 7 (satisfactory). Many researchers agree that although green buildings often tend to be hotter in summer, colder in winter and have more glare from the sun and sky than their conventional AC alternatives [14,15], the occupants tend to be more forgiving. Furthermore, Kwok and Rajkovich [27] discuss this toleration of moderate discomfort and suggest that occupants may have an understanding of, and connection with the outdoor climate by virtue of the building's design, suggesting that increased knowledge of the adaptive opportunities in buildings, such as operable windows, individual shade control, aesthetics and glazing area, etc. yields a greater likelihood of reduced discomfort [16].

1.3. Environmental attitudes, behaviours and the New Ecological Paradigm (NEP)

In recent decades there has been a growing awareness of the problematic relationship between modern industrialised societies and the physical environments upon which they depend [28,29]. With the emergence of pervasive environmental problems such as climate change, many researchers have started exploring how to quantify public sentiment on these issues. Environmental attitudes represent a psychological tendency expressed by evaluating the natural environment with some degree of favour or disfavour [30,31]. Attitudes are related to other psychological and cultural dimensions, e.g. beliefs, intentions and behaviours. Since attitudes are a latent construct, they cannot be measured directly, and thus need to be inferred from overt responses [32]. A proliferation of environmental attitudinal measures has been proposed since the 1960s, the problem arises of using a reliable and valid set of measures or scales in order to quantify the unquantifiable [30,33].

The New Ecological Paradigm (NEP) Scale [1] is a revision of the NEP developed by Dunlap and van Liere [34]. This 15-item questionnaire consists of 8 pro-NEP and 7 anti-NEP items developed to measure strength of endorsement (from low to high) of an ecological worldview [29,35]. After extensive application across a diverse range of studies, a broad consensus is emerging in the environmental psychology literature that the NEP represents a valid and reliable scale for measuring levels of ecological beliefs and behaviours [36]. Despite its extensive use, the NEP scale has not been used in conjunction with building occupant studies and could potentially identify the link between successful occupancy of green buildings and environmental attitudes. Thus this paper investigates the hypothesis that broad environmental attitudes are closely associated with the stronger 'forgiveness factor' often observed in green buildings.

2. Methods

2.1. Sydney's climate

The Sydney metropolitan region is located on the eastern coast of Australia (34°S, 151°E) and is characterised by a moderately temperate, sometimes called humid sub-tropical climate. Influenced by complex elevated topography surrounding the region to the north, west and south and due to close proximity to the Tasman Sea to the east, Sydney avoids the high temperatures commonly associated with more inland regions, as well as the high humidity of tropical coastal areas [37]. The summer months of December to February can be described as warm-to-hot with moderate-to-high humidity peaking in February to March. Between June and August, Sydney experiences cool-to-cold winters. The tertiary institution is located in Sydney's suburbs, 16 km out of the Central Business District of Sydney. Seasonal variations are fairly consistent with the greater metropolitan region with a mean summer daily maximum temperature of 26–28 °C, a mean winter daily maximum of 17 °C and an annual mean daily maximum of 22–23 °C. Mean minimum daily temperatures range from 5–8 °C in winter, to 17–18 °C over the summer months, with an annual daily minimum temperature of 11–13 °C [38]. Given these yearly seasonal variations, Sydney's

$$\text{Forgiveness factor} = \text{Comfort overall}/\left(\frac{\text{AirW}+\text{AirS}+\text{TempW}+\text{TempS}+\text{Light}+\text{Noise}}{6}\right) \quad (1)$$