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An analysis of occupants response to thermal discomfort in green and conventional buildings in New Zealand

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ABSTRACT

Studies have found high discomfort issues in green buildings where occupants find it too cold during the winter and too hot during the summer. Green buildings are highly climate responsive since they are usually dependent upon natural ventilation and natural daylight. In conventional buildings, occupants are not so dependent on the building design to moderate temperature and lighting. This paper investigates occupants responses to discomfort in conventional and green buildings to better understand how they behave, and whether they behave differently. This study examines what people do when they are too hot or too cold. Three coping mechanism were tested (i) environmental adjustment, (ii) personal adjustment and (iii) psychological adjustment. Results in this paper showed that in response to being cold, occupants in green buildings engaged more in personal adjustments, less environmental adjustment, and more in psychological adjustment compared to conventional buildings. While in response to being hot, these coping mechanisms were less apparent. The paper examines what adjustments people make when they are too hot or too cold, and compares these behaviours in different building types.

1. Introduction

Thermal comfort is defined by the International Standard American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) as "*that state of mind which expresses satisfaction with the thermal environment*" [1]. Green buildings, which are mostly mechanically and naturally ventilated buildings adopt the ASHRAE 55 2010 [1] and ISO 7730 [2] guidelines which suggests a thermal comfort temperature between 20 °C and 24 °C. Studies showed that the thermal comfort at these temperatures is generally accepted by the occupants [3–5]. Post occupancy studies on comfort have shown that in general green buildings are more comfortable compared to conventional building [6,7].

Although the temperature of 20 °C to 24 °C is an accepted comfort range for most occupants, Nicol and Humphreys [8], argued that the temperature range advised by ASHRAE 55 2010 [1] standard and ISO 7730 [2] guideline is too narrow. This is supported by other studies that found high discomfort issues in green buildings where occupants find it too cold during the winter and too hot during the summer [9–12]. Occupants will perform environmental adjustment buildings when they are experiencing discomfort in thermal, daylight and natural ventilation in the building [13–17].

The adaptive thermal comfort model (i.e. International standard ASHRAE RP884 [18] and European Standard EN 15251 [19] proposes a wider temperature range up to 30 °C and claims that buildings should be designed in a way that provides wider opportunity for occupants to adopt behaviour adaptations [8,20,21]. The adaptive thermal comfort model is not widely adopted in a controlled thermal environment such as an air-conditioned building [4]. This is because there is a huge challenge in behavioural change as it requires a lifestyle change that is too onerous [4,22].

Scholars have listed examples of behaviour adaptations in response to discomfort to being cold and hot [8,14]. There are three types of behaviour adaptations which are (i) personal adjustment—i.e. *adjusting activity, adjusting posture*, (ii) technological or environmental adjustment—i.e. *turning on fans or heaters* and (iii) psychological adjustments—i.e. *just put up with it, or try to ignore the problem.* However, limited studies have been conducted on the level of practice of these behaviours. By investigating the level of practice of behaviour adaptations to thermal comfort it is possible to gain a better understand how buildings can encourage more behaviour adaptations.

Environmental adjustments have energy implications for the building. Among the post-occupancy issues in green buildings are lack of knowledge and skills on how to operate the environmental control systems efficiently [23–25], and limitation of accessibility to the control systems which caused occupants to make their own personal modifications (i.e. *use personal fan, heater, and etc*)

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Table 1
Personal adjustment.

Personal adjustment	References
clothing adjustment when felt cold and hot	[14,23–28]
alter timing of their work pattern to avoid uncomfortable working conditions	[23,25,27,28]
adjusting posture	[25]
consuming hot or cold food and drinks	[14,23,25,26,28]
moving to a different location	[14,23–25,27–30]
taking a walk inside or outside	[14,26]
contact building manager	[14]
share the problem with co-workers to see if they are also experiencing discomfort	[14]

to achieve optimum comfort [16,23,26]. Studies have also found that occupants' desire to achieve optimum comfort caused controls to be overridden, such as mechanical cooling and heating systems [16,17,24]. Against the need to change controls, Heerwagen and Diamond [14] suggest that an adverse impact of providing good automated building control systems is the "*desk couch potato*" where there may be a lack of muscle movement, and an increase of social isolation.

Heerwagen and Diamond [14] examined the three types of behaviour adjustments (personal, environmental, psychological) in green buildings. The findings showed that the green buildings encouraged more personal adjustments than environmental adjustments. Personal adjustments were made more than environmental adjustments in spaces which occupants have limited access to the control systems such as the open plan space. While in private offices within the building, the occupants made more environmental adjustments than personal adjustments.

Advocates for personal adjustments believe it not only helps reduce energy consumptions in buildings, but it is also believed to create healthier personal actions for the occupants since there is more muscle movement [4,14,27].

In order to further the debate about thermal comfort in buildings, the study in this paper examines what people do when they are too hot or too cold, and whether there are significant differences in the behaviour of occupants between green and conventional buildings.

2. Coping mechanisms in response to discomfort

Reviews of the international literature showed that there are three basic types of coping mechanism in response to discomfort that occupants normally take in buildings [14,21]. These coping mechanisms are (i) personal adjustment—i.e. *adjusting activity, adjusting posture*, (ii) technological or environmental adjustment—i.e. *turning on fans or heaters* and (iii) psychological adjustments—i.e. *just put up with it, or try to ignore the problem.* Table 1 provides a detailed list of adjustments considered to be personal adjustments in response to thermal discomfort.

As shown in Table 1, clothing adjustment is a common personal adjustment made in response to discomfort. This behaviour has been promoted in office buildings. For example, a campaign on no neck ties in Japan in 2005 [28] and employees were encouraged to adopt casual dress code in United Nation Headquarters, New York [29]. The rationalisation for this campaign was that flexibility in dress code in office buildings provides occupants more adaptive strategies to cope with thermal discomfort. O'Connor et al. [30] categorised these behaviour changes as "suffer discomfort". Although discomfort is not relieved entirely by personal adjustment, these behaviours have important functions such as making people move around more and engage in social interactions [4,14]. The mental and social benefits generated from personal adjustments are worthwhile and create a healthier environment for the occupants. There are limited understanding on whether the design of a green building encourages occupants to engage in personal adaptation [27,31,32]. For example, Healey and Webster-Mannison [27] reported that occupants engaged in more personal adjustments (i.e. dress in layers, cons umed hot/cold beverages, disposition) due to the influences of the socio-cultural aspects within the building, but did not relate the adaptive behaviour responses to the physical environment in the building. Moezzi and Goins [33] reported that occupants in commercial buildings engaged in less personal adjustments (i.e. drink hot/cold beverages; dress in layers, walk around more) than environmental adjustments and speculated that it is due to the lack of physical environment such as a place to buy coffee, and a place to retreat. However, findings by Gauthier and Shipworth [34] showed a different result to Moezzi and Goins [33] where physical environment does not necessarily encourage occupants to engage in personal adjustments. Several earlier studies indicated that building design features such as spacious common room and access view to the natural environment reduces occupants stress level and increases work productivity [35–38].

Environmental adjustments are how occupants interact with the building control systems (i.e. windows, blinds, switches, and other controls). Occupants who engage in this thermal discomfort coping mechanism can impact energy usage if the building control systems are not operated efficiently. Inefficient operation of the building control systems are described in the following studies. For example, Gabe [24] and Sawyer et al. [17] discovered that occupants increased the load of the cooling and heating systems to accommodate comfort. Reiss [16] discovered that occupants routinely override switches for natural ventilation or mechanical cooling because they don't know what conditions each option is intended for. Reiss [16] also discovered that occupants did not open the window when they were supposed to which caused the heating system to consume energy five times more than predicted. Heerwagen and Wise [39] showed that occupants kept doors open for fresh air causing mechanical systems to consume more energy. Bordass et al. [23] and Brown [40] reported that occupants used personal heaters or fans to relieve discomfort. These studies led to the assumption that when occupants are provided with high access to the environmental control systems, they will be more likely to make adjustments that will impact energy usage in buildings [14,26]. This prediction was further supported by findings from Ricciardi and Burrati [41] and Moezzi and Goins [33] where the occupants engaged in less environmental adjustments when they had limited access to the building environmental control systems. O'Brien and Gunay [42] raised concern that contextual factors such as occupants' awareness and perception of working in a green building can influence their choice of adaptive behaviour. For instance, occupants may adopt poor energy saving behaviours in energy efficient design buildings due to the 'rebound effect' [43,44].

Heerwagen and Diamond [14] defined psychological coping mechanism as an attempt to adjust to a situation by managing emotions or thoughts about the situation. Occupants responded to either feeling hot/cold by just putting up with the discomfort, believing there was nothing they could or trying to ignore the discomfort. Heerwagen and Diamond [14] found that almost one fifth of the occupants who experienced thermal discomfort either feeling too hot or cold chose to not do anything. Occupants engaged more in this coping mechanism when environmental adjustments are limited, and when other coping mechanisms' are not effective to relieve discomfort.

Previous studies describe adjustments made by occupants to relieve discomfort. These studies did not quantify the frequency of the behaviours. Quantification of the frequency of behaviours can aid building designers to make better prediction of energy usage. Current energy modelling software assume occupants schedules