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Applying contextual understanding in mixed mode design: a user-centred study of thermal comfort and adaptive control

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Abstract

In achieving low-energy operation, occupant-controlled mixed mode buildings rely as much on the judicious use of active climate control by occupants as they do on the efficiency of the building services. The extent to which occupants choose to use natural ventilation for creating a thermally comfortable environment is informed in part by the human heat balance, and by the availability and effectiveness of adaptive comfort devices, but is also a function of social, cultural, and local context. Qualitative study is suited to exploring these factors in more detail. The paper presents a case study using qualitative interviews, focusing on an occupant-controlled mixed-mode office building in the warm humid climate zone of Australia. Occupant attitudes which tend to entrench the use of natural ventilation or, conversely, active climate control, are identified, and these are used to create guidelines for encouraging the judicious use of energy by occupants.

Keywords: Mixed mode, adaptive thermal comfort, qualitative research

1 Introduction

In pursuing low energy operation, occupant-controlled mixed mode buildings should aim to minimise the proportion of time the occupants choose to rely on active climate control. Such buildings rely on the efficient use of energy by the building services and the judicious use of energy by the building occupants. The building design should provide, in order of priority, climatically appropriate passive design strategies which take advantage of and temper external conditions, personal adaptive devices reflecting the comfort preferences and functional needs of the occupants, and finally, active temperature control systems which can be used when climatic extremes exceed the limits of passive and personal adaptive responses.

A great uncertainty in mixed mode design is in anticipating how occupants will use adaptive comfort devices, and under what circumstances they will choose to use active systems. These questions can be answered in part using predictive (quantitative) comfort models. However, comfort models are by necessity context-free and do not provide guidance of, for example, to what extent the occupants value energy conservation, or how they judge the quality of a naturally ventilated environment. As a result, the greater the low energy design strategy relies on occupant control, the more difficult it is to predict the building's eventual energy use. This uncertainty can make occupant-controlled buildings a less attractive prospect, despite their potential to achieve significant energy savings, and can compel designers to err on the side of a more predictable design strategy. Analogous problems with the way we assess the performance of naturally ventilated buildings has been previously raised by others (e.g. Roaf et al, 2010).

The adaptive comfort model is valid for fully naturally ventilated buildings, and can for mixed mode provide guidance of the thermal conditions under which occupants will become uncomfortable and choose to use active systems. Quantitative studies of occupant control (e.g. Baker and Standeven (1994), Brager et al. (2004), Haldi and Robinson (2010)) can be used to inform energy modelling algorithms. Qualitative understanding of the occupants, their social and cultural setting, and climatic and local context can complement these approaches by considering behaviours that occur outside of the deterministic relationship between the thermal environment and occupant comfort. Applying this insight can improve low-energy building design whilst considering in more detail the needs of occupants, and should help produce buildings which are comfortable, low energy, and judged positively by occupants over the long term.

Qualitative study can improve understanding by exploring the acceptability of adaptive practices and experiential dimensions in favour of temperature-based comfort limits (Hitchings, 2009). Such an approach aims for thermal delight, rather than neutralisation, by enhancing sensory experience and valuing the quality of indoor environments (Heschong, 1979). Chappells and Shove (2005) identify these two contrasting considerations of comfort; comfort as universally definable state as per the quantitative, deterministic model, and comfort as a socio-cultural achievement, or the qualitative, constructivist model.

A user-centric approach (Vischer, 2008) recognises both the value and limitation in environmentally deterministic study of built spaces, and likewise in the constructivist approach which considers sociocultural context. Applying Vischer's user-centred theory combining both worldviews is suited to the mixing of quantitative and qualitative research paradigms, asking dual questions:

- What is the effect of the indoor environment and building systems on comfort?
- How do people feel about and respond to the built environment?

It is the second question which is the focus of this paper, in the context of an occupant-controlled, mixed-mode study building. The first question was examined for the same building in a previous work (Healey, 2014) and key results are outlined below. A post-occupancy evaluation has also been carried out by others (Best and Purdey, 2012).

This paper argues that the social, cultural and climatic context of the building and its occupants can tend to entrench a culture of comfort achieved primarily via natural ventilation and the judicious use of energy for climate control, or can entrench a culture which defaults to the unrestrained use of energy for the achievement of comfort. The paper identifies key themes in achieving and mediating the balance between the building and its occupants to create an environment which is comfortable and of low energy consumption.

1.1 Study building

The study focuses on administrative and academic staff occupying mostly one- and two-person offices over two levels of a three-storey building at Bond University on the warm humid Gold Coast in Queensland, Australia. The climate is comfortable for much of the year, excepting cool winter mornings and hot, humid days in summer. The building has a high profile as an example of a sustainable development and has received multiple awards for its environmental design. Many of the occupants play a role in promotion of the building through facilitation of building tours.

The building has changeover mixed mode air conditioning systems used for climate control, interlocked with openable windows and internal doors, with each office having an independently user-operated system. The only constraint to the use of the air conditioning system was a building-wide natural ventilation mode which is enforced when external conditions are between 19 and 25°C. Each office is controlled by a hotel-style key switch, or 'office ignition', which must be turned on by the occupant in order for the lighting, HVAC, and ceiling fan to be used.

Previous work demonstrated a general preference for natural ventilation among occupants (Healey, 2014). The use of air conditioning was limited by a number of non-thermal factors:

- The need to maintain a sociable working environment and to present a welcoming impression to visitors meant that internal doors were normally left open, precluding the use of the air conditioners;
- The inconvenience of having to stand up to turn on the air conditioning system via a wall-mounted panel;
- Intermittent office occupancy combined with the hotel-style key switch reduced the amenity of the air conditioner, as it forced shut-down when vacating and there were subsequent start-up delays when the room was reoccupied;
- A desire among occupants to use energy frugally and to be seen to be doing so;
- A preference for natural ventilation, including a perception that natural ventilation was healthier than air conditioning; and
- A demonstrated tendency to tolerate considerable discomfort before making an adaptive action to restore thermal comfort.

All occupants reported using the heating for up to one month of the year, if at all, and around three quarters reported using cooling for up to one month, with the remainder using cooling more often (Healey, 2014). This is significantly less than was predicted in design, when it was estimated natural ventilation would be used for two months of the year (Healey et al, 2007). Reliable energy consumption data was not available.

2 Methods

The study involved one-on-one, semi-structured qualitative interviews with 28 occupants, generally of around 20 minutes duration per occupant. Interviews are useful for learning how individuals feel about, perceive and react to their environment (Zeisel, 2006). Semi-structured interviews follow a checklist of topics with default wording and order for the questions, but can be modified based on the flow of the interview and supplemented with unplanned follow-up questions (Robson, 2011). This structure allows flexibility and depth in responses, and was adopted in this study in order to explore occupant experience in the occupants' own words. The interviews avoided jargon typical of conventional thermal comfort questionnaires, and covered the following general topics:

- General opinion of the building including likes, dislikes, knowledge and confidence in its operation, and the impression the building gives to visitors;
- Opinion on the environmental sustainability of the building, and whether this is important to the occupant;
- Experience of thermal comfort and discomfort, use of adaptive comfort devices, and approach to adaptive comfort at home;
- Experience of noise, lighting, and other non-thermal indoor environment quality issues;

- Dress code and clothing adaptation;
- Open-ended questions providing the opportunity for further comments; and
- Any impressions of interviewer bias.

Thematic coding was used to sort and analyse the data, using NVivo software. This process involves tagging passages of transcribed interviews according to the topic of discussion, allowing themes to emerge rather than being imposed. The themes were then examined to identify issues of importance to occupants and common experiences or perceptions, and these were then considered in terms of their interaction with the cultural setting, and whether they tended to entrench the judicious, or unrestrained, use of energy. These results were used to develop understanding of how the social setting, the environment, and the local context mediate the balance between occupant comfort and energy consumption.

Interviews, particularly those with looser structures, can be problematic in their relationship to theory, in data reliability, and in analysis. In using these methods, research techniques must display awareness of potential issues and respond appropriately. Potential issues include:

- **Standardisation and reliability**: the validity of comparing data from different occupants can be questioned where a standard process was not followed. In this case, each interview was different due to the adoption of a loose structure, allowing different questions to be asked. For each interview, a common 'map' was followed, and each was conducted within a single block of time and by the same interviewer.
- **Interviewer bias**: perceived bias of the interviewer can cause interviewees to colour their responses. In this case, the emphasis on the sustainable design aspects of the building may have caused occupants to 'talk up' their environmental awareness. One method of identifying bias (Robson, 2011) is to ask interviewees directly of their perceptions of bias at the conclusion of the interview. 25 occupants responded to this question; of these, none raised any concerns regarding bias or leading questions.
- **Trustworthiness**: trustworthiness in flexible research designs such as semi-structured interviews can be difficult to establish, due to the lack of explicit controls, measurements, or repeatability (Robson, 2011). Procedures adopted for demonstrating credibility included audio taping to ensure a valid descriptive record, inclusion of contradictory results in the analysis, mixing of methods to include standardised research designs, as has been previously published (Healey, 2014), and triangulation with other relevant existing research (see Best and Purdey, 2012).

3 Results

This section details the themes and provides examples of occupant responses, and a short summary of the responses is provided at the end of each section. Where occupants were asked about a particular aspect directly, a greater number of responses were received. Other results were not gained via direction questions and instead were volunteered by the occupant; unsurprisingly, these emergent responses tended to be lower in number.

Four key themes emerged from the interviews; the perceived health risks of air conditioning, the impact of the social setting, the impact of the physical setting, and the level of knowledge on the part of the occupants.

3.1 Perceived health risks of air conditioning

A widely held perception was that air conditioning was unhealthy due to air recirculation, low humidity, and dirty filter media (Table 1). This perception was not specific to the building but was a generally held personal view of air conditioning, and is an example of a 'folk theory' (Strengers and Maller, 2011) through which people express their preference or dislike and form their understanding of how air conditioning should be used. The corresponding perception in which natural ventilation has a positive influence on health was also held. There were two exceptions where occupant of cooling-reliant thermal disposition (Healey and Webster-Mannison, 2012) felt distress or excessive discomfort when prevented from using active cooling.

The perceived role that air conditioning systems play in the transmission of illness within a workplace was seen as important. The study building was judged as healthy due to the option of not using air conditioning, the absence of a return air path, and the small occupancy of most offices.

> *… if you sit in an air conditioned environment you just catch everything.*
>
> *I'm not a big fan of the way it circulates and you can get sick if someone else is sick. I've heard a lot of that happening. But I don't know exactly how it all works and if that is true.*

The quality of air provided by the air conditioning system, especially the dryness and cleanliness of the air, was seen to contribute to ill health. Likewise, open windows and access to breezes were seen as very positive qualities.

> *I just feel like I'm dried out. I don't think it's good for your body.*
>
> *It's dry air, it's mechanically treated, so it's artificial air for me. It has to run through a filter whereas we could have fresh air from outside.*

Air conditioning influences physical comfort, in terms of thermal and respiratory comfort, but also psychological comfort, in the occupants' interpretation of health impacts. This perception reinforces itself as it continues to be experienced and shared between occupants, and hence tends to support the use of natural ventilation in preference to air conditioning and entrenches a culture of energy judiciousness. As a folk theory, it is independent of the building and the organisation, but instead exists within the broader cultural setting.

The result is that many occupants chose to operate the air conditioning for limited periods of time as a kind of corrective action, defaulting back to natural ventilation when conditions were suitable.

Table 1. Summarised responses - perceived health risks.

Topic	**Direct question?**	**Supporting responses**	**Contradictory responses**	**Notes and clarifications**
Unhealthiness of AC	No: occupants were asked their general opinion of AC	11	2	Many felt AC remained a necessity for comfort in this climate.

3.2 Impact of the social setting

The occupants were asked to share their views on the social setting (Table 2). Social conditions within the building had created an expectation that occupants use, and are seen to be using, energy and other resources conservatively. This has come about partly through planned organisational measures, and also spontaneously.

Deuble and de Dear (2012) found that 'green' occupants with pro-environmental beliefs were more forgiving of suboptimal indoor conditions than their non-green counterparts, and that this was more so the case for occupants of green buildings. The study building accommodates staff from a school of sustainable development, indicating a high level of environmental awareness, and most stated that they valued working in a sustainably-designed building. Additionally, some felt it important that they were seen by students as fulfilling their responsibility to demonstrate a pro-environmental attitude.

> *So yes, it is important for me to believe it is sustainable for me to teach them … because if I don't believe it they pick up on it, they notice, she's just saying something she doesn't believe.*

Interestingly, several occupants felt the experience of working in the building had cultivated their own interest in sustainability and that they had subsequently changed their habits both at work and at home.

> *Is it really going to save the world, putting a can in that bin other than that bin? But since I've started here I've changed that mindset. So it's pushed me in that direction and I'm finding it more and more important.*

> *I used to use the dryer a lot and leave things on, but I've bought a clothes airer and a clothes line and I use that now. I turn the TV off at the TV and not just with the remote now. I am changing the way I think. I use less water.*

The manager had played a role in influencing organisational culture; one example being their response to initial comfort complaints by placing responsibility for achieving thermal comfort with the occupants, rather than with the building.

> *When the staff first moved into this building ... It was an unusually wet and cold day, and I got some unusually aggressive emails from some of my staff saying, "this is a horrible building, it's cold," and so I just said, "put a jumper on". And that's the philosophy, you dress for it.*

Peer expectations motivated occupants to conserve energy, and not be seen wasting energy. This had created feelings of guilt among those with a greater reliance on cooling; likewise, occupants portraying energy-saving behaviour felt virtuous. Occupants framed their energy use in terms of a perceived personal 'quota' and used this reasoning to justify it. There was no tangible feedback provided to occupants on actual energy consumption – neither on a whole building nor an individual level – and hence all of these effects were based in perception.

> *I am somewhat self-conscious of the fact that I have a need for air conditioning.*

> *[There is only] that month in summer and month in winter when I do use the air conditioning. And I still feel fairly virtuous because I know the rest of the year I don't need it.*

…considering there's two people sharing [the office] I think that's a bit better – splitting the air conditioning.

Some social constructions favoured the use of climate control. Consideration of the comfort needs of visitors is a strong motivator linked to notions of cooling as a socially hospitable practice (Strengers and Maller, 2011), and climate control as a symbol of corporate prestige (Chappells and Shove, 2005). There can be a tendency to assume that others prefer air conditioning and consider it 'normal', and that natural ventilation is a second-rate option.

I probably should turn it off … but I think that if I come back and I have a student waiting, this office is so hot …, how do they feel? I'm thinking of them as well.

Finally, occupants interpretation of the appropriate mode of dress had an impact in some cases. Most felt that they could dress to the conditions, with the summer conditions being more limiting, but some constrained their ability to dress for comfort based on a need to appear professional and to avoid 'looking like a student'.

Table 2. Summarised responses - social setting.

Topic	**Direct question?**	**Supporting responses**	**Contradictory responses**	**Notes and clarifications**
Values a sustainable workplace	Yes; "Is it important to you that you work in a sustainable building?"	20	6	Contradictory responses included those ambivalent or neutral.
Has changed own habits to be more pro-environmental	No: raised after discussing values	3	-	Many other occupants claimed to be already practicing pro-environmental behaviours.
Perceived peer expectations assigning a moral value to energy use	No	6	1	Many other occupants expressed consciousness of energy use. Contradictory response was "do as I say, not as I do".
Concern for comfort needs of others	No	2	-	
Able to dress to the climate most of the time	Yes: "Does the dress code affect your ability to dress to the climate?"	20	7	

3.3 Impact of the physical setting

Environmental determinism in thermal comfort research is normally involved with relating the human heat balance and comfort, or understanding the use and impact of adaptive comfort devices. In addition, aspects of the physical environment influence physical, functional, and psychological comfort through cues, reminders, constraints and processes embedded into the architecture, building services and control systems. The study building's control devices including sensor lighting, manual and automated comfort systems, and the office ignition, had an impact on the way the occupants felt about their building and influenced their behaviour accordingly (Table 3).

Devices and systems which were well-designed had a positive impact by providing reminders of the sustainable qualities of the building and by guiding occupants in its correct operation. Reminders served to maintain awareness of embedded sustainable design features, for example by using motion-sensor lighting in intermittently occupied shared spaces such as bathrooms. Visible reminders can entrench a culture of energy-judicious behaviour by demonstrating that the building is upholding the same responsibility to conserve energy that is requested of the occupants.

> *The fact that when you walk into a room the lights turn on, and when you go out there's no movement and they turn back off. You notice that and appreciate it.*

Controls which guide occupants in the low energy operation of the building impose a small inconvenience barrier without unnecessarily interfering with occupant comfort or functional needs. The office ignition and the window interlocks with the air conditioning were successful in achieving this, although Brager (2009) notes that window interlock systems tend to be disliked in more open plan-style workplaces. Features which guide occupant behaviour additionally provided assurance that other occupants were operating the building correctly, which helped cultivate a culture of shared responsibility.

> *As annoying as it is to have to put your keys in there, it's actually pretty good because it forces you not to be lazy about leaving stuff on.*

> *The fact that you can open the window, that it acknowledges if you want to put the air conditioning on, that you can't if the window is open … little programs like that I think are effective. Because not everybody thinks about that, they'll turn on the air conditioning and not think, should I shut my window or shut my door.*

In general, successful controls are those which match occupant expectations with their experience of the building and are achieved via a fully developed and executed design concept.

Dysfunctional controls include those which interfere with occupants' functional needs, particularly when this occurs in the presence of others (i.e. students and visitors), and these were identified as an issue in both the post-occupancy evaluation (Best and Purdey, 2012) and the interviews.

> *The things I don't like are the sensors for the lights, since I'm just here in front of my computer and my work is just sitting here reading and writing, and I don't move much, so if you don't move like in 10 minutes, then the lights don't turn on.*

Systems which do not directly affect occupants, but visibly waste energy, create feelings of resentment as occupants see their own energy-conserving behaviour compromised by poor design, as though the building is not upholding its side of the arrangement. This can erode the culture of energy-judiciousness.

> *I do find it very often annoying that the lights go on without needing to be on and things like that, you just go, come on really do we need this?*

Table 3. Summarised responses - physical setting.

Topic	Direct question?	Positive experiences	Negative experiences	Notes and clarifications
Building automatic controls	No: raised while discussing building services generally	8	15	Some occupants reported both positive and negative experiences

3.4 Knowledge of and engagement with the building

A widely-recognised barrier to realising lower energy use in buildings is correct operation by occupants, supported by knowledge, training and engagement. This was especially the case for the study building as it relied on occupant choice between natural ventilation and active climate control. In the interviews, occupants were asked about their knowledge of and confidence in operating the building correctly (Table 4).

A building users' guide (BUG) describing the features and operation of the building was produced and made available to the occupants, although many were not aware of it. In addition, a series of information panels were placed around the building describing environmental design features, such as automation, efficient plant, and recycled materials. Building tours were conducted regularly by some staff.

These intentional measures to train and engage staff in building operation had varying success, and some unplanned impacts. The BUG and information panels present the building as a modern design with complex automation, which may have caused some occupants to underestimate their ability to operate it confidently. However, all understood the functional control of their usual workspace to an adequate degree. There was a deficiency in some occupants' ability to properly operate less familiar spaces, partly due to lack of training and partly due to dysfunctional or confusing controls design.

> *No. I probably wouldn't know how to… know about all the facts and features down there in that room, I wouldn't know how to operate it, but as far as being able to put the key in the wall and turn on the air conditioner ...*
>
> *…as far as my office, yes, but when it comes to our staff common room down the end I'm never sure what happens with the air conditioning in that room.*

Those occupants who conducted building tours benefited from a more thorough understanding of the building. Aside from this, the tours had unplanned benefits; the presence of the tours served as a reminder to all occupants that their building was of

noteworthy design, which fostered a sense of awareness and pride. This provided motivation to engage in and maintain its proper operation. The ongoing nature of the building tours meant that they were far more effective in retaining knowledge and engaging staff, particularly when compared with the BUG, which has not been well used.

An important aspect of information and engagement is the provision of feedback on the building performance to occupants, in order to demonstrate the outcomes of their efforts. This is especially the case, given the need to maintain a culture of judicious resource use, and the extent that responsibility for resource use is placed with the occupants. While there is a building performance information display, information is not provided directly to the occupants in a meaningful context; as a result, there is little demonstration that occupant efforts in carrying out pro-environmental behaviours are having the intended effect.

Table 4. Summarised responses - knowledge and engagement.

Topic	**Direct question?**	**Yes, with reservations**	**Yes**	**Notes and clarifications**
Understands how to operate the building	Yes: "Do you feel you understand how to operate the building properly?"	14	12	Own perception and hence related to confidence.

4 Discussion

4.1 Occupant attitudes

The results are summarised here, re-worded to illustrate the occupants' attitudes in simple terms and grouped according to their theme (Table 5). In the context of the research question, these attitudes have one of two outcomes; they can tend to entrench a culture which values the judicious use of energy, and default to natural ventilation, or can tend to entrench a culture where energy use is not restrained and active climate control is the default, and are categorised along these lines.

Table 5. Occupant attitudes influencing expectations and comfort.

Attitudes which favour judicious use of active climate control	**Attitudes which favour default use of active climate control**
Perceived health risks of air conditioning	
Air conditioning is unhealthy	Air conditioning is normal and necessary
Natural ventilation is healthy	Natural ventilation is uncomfortable
Air conditioning is there just for when it is really needed	Air conditioning is the default setting
Impact of the social setting	
I want people to see I care about the environment	There are no social consequences of my using energy
Achieving a low-energy building is everyone's responsibility	Achieving a low-energy building is the responsibility of the building designers and facility manager
Achievement of thermal comfort is my responsibility	The building should provide a thermally comfortable environment
I shouldn't use more than my fair share of energy	The amount of energy consumed is not my concern

I assume others are comfortable without air conditioning; if not they will tell me	Having the air conditioning on is a common courtesy to visitors
I dress for comfort, within reason	I dress for appearance
Impact of the physical setting	
I notice the building does not use energy unnecessarily	I notice the building is wasting energy
The building provides helpful prompts to save energy	The building interferes with my functional needs
The building provides guidance on how I need to operate it	It is not obvious how to operate the building; as a result I sometimes appear foolish
Knowledge of and engagement with the building	
I feel confident operating the building	I feel intimidated by the building's complexity
I am proud of working in this building	This is just a building
I receive meaningful feedback so I know my efforts have an impact	I don't know if the building is living up to its design intent

4.2 Guidelines

The attitudes listed in Table 5 relate to comfort and satisfaction not as a result of the deterministic relationship described in quantitative models, but as a result of socio-cultural constructions, including as a response to the built environment, a response to social conditions, or informed by cultural understandings of 'healthy' and/or 'normal'. Following this line of reasoning, just as built environments can be designed to operate within a certain range of thermal parameters, they can be intentionally designed and managed to influence occupant attitudes in favour of judicious energy consumption, to some degree. This leads to the formulation of tangible qualitative design guidelines for occupant-controlled, low-energy buildings which complement the existing strategies of appropriate passive design, effective adaptive comfort devices, and efficient active systems. The guidelines look at each pair of attitudes and consider whether they can be utilised in design and management.

4.2.1 User experience of building controls

The results identified that aspects of the physical setting had an impact on the occupants' functional and psychological comfort, and that these could lead to the entrenchment of certain attitudes. These attitudes emphasised a desire for the building to actively conserve energy where possible, just as is expected of the occupants, and for it to support the occupants' own efforts by striking the right balance between inconvenience and encouragement, and by being intuitive.

These conclusions are obvious, and have been well-documented by others (e.g. Leaman, 2003), but often not achieved in reality. It is argued that extra attention to detail regarding the inadvertent implications of the user experience is warranted.

In applying this understanding, building controls should be considered in terms of the space's functional relationship to the occupant in terms of whether it is common or working area, and therefore whether the operation of the space is the responsibility of the building or the occupant.

Systems serving common spaces such as bathrooms and circulation are normally the responsibility of the building and therefore automated. They should:

- Ensure energy is not wasted, for example lights which needlessly illuminate well-daylit spaces; and
- Provide visible evidence that remind occupants that the building is operating efficiently.

Systems serving occupants' normal work areas can be placed in the responsibility of the occupant, and should aim to support them by:

- Trusting the occupant to operate them correctly and hence allowing full manual control;
- Providing prompts which remind occupants of their intended use and guide in their correct operation;
- Ensuring any inconvenience factor does not interfere with the functional needs of the occupants; and
- Assuming that occupants will establish a habitual, default setting for their workspace, and that their daily use means occupants can tolerate a greater level of system complexity (within reason).

Systems serving areas used intermittently, such as meeting rooms and function spaces, should aim for a lower level of complexity than areas used regularly, appreciating that occupants will need to be able to operate them intuitively on short notice. They should:

- Include full manual override to allow for immediate changes and future flexibility; and
- Provide instructional labelling.

The issue of assigning responsibility for control in shared workspaces, such as open plan offices, is less clear-cut, and requires special consideration. Further comment is provided in the conclusions.

4.2.2 Organisational expectations

The first set of guidelines requires the designer to consider whether responsibility for control lies with the building or the occupant. Where responsibility is assigned to the occupant, there is an accompanying role for organisational leadership in actively setting expectations accordingly. Once again, this is an obvious statement, but one which in practice is often not acted upon in full.

While many aspects of the social conditions which exist among building occupants cannot be controlled or planned for, organisational leaders can exercise influence. Their goal should be to set an expectation that achievement of comfort is primarily the responsibility of the occupant, and to engage with the design themselves by visibly valuing the quality of a naturally ventilated environment. Obviously, expectations of dress standards must support adaptive comfort needs.

Engagement of organisational leaders in the mixed mode design concept also involves reality-checking; as noted by others (e.g. Chappells and Shove, 2005), organisations need to be clear as to what extent they are willing to go along with unconventional practices, such as relaxed dress codes.

4.2.3 Information and engagement

The third set of guidelines involves effectively engaging the occupants. As with the other guidelines, while this is obvious, it is the inadvertent implications of addressing these needs well (or addressing them poorly) which are of interest here. This is also tied to the readability of the controls. In this case, the focus is on building a sense of

confidence and pride, and taking advantage of existing tendencies. A number of ideas were raised in the results:

- Measures which identify the building as noteworthy, such as unconventional design features, design awards, and the running of building tours can help foster a sense of awareness and pride among occupants, as well as a sense of responsibility in its proper operation;
- Ongoing implementation of such measures can maintain this engagement over time. The building tours were particularly effective in the case of the study building, and were still being conducted three years after initial occupancy, which also helped to engage new staff; and
- Feedback of the building's energy performance should inform occupants of their contribution to measureable goals, and in doing so exploit an existing tendency for individuals to perceive consumption in terms of their 'fair share'.

4.3 Aspects outside the influence of design and management

User-centric consideration of the built environment recognises that both the physical environment and the socio-cultural context influence the user experience. The physical environment can be designed to influence thermal comfort, both in terms of the thermal environment, and as argued here, in terms of its influence on functional and psychological comfort.

There is much more limited opportunity to influence socio-cultural constructions of comfort. However, these results provide a richer understanding of how the social and cultural context influences consideration of comfort, and can assist in selecting the appropriate design approach. These types of themes included:

- Perceptions of the health of air conditioned versus naturally ventilated environments. This should be treated as a folk theory which favours passive design strategies;
- Social consequences, or lack thereof, of using energy conspicuously among the specific user group;
- Self-imposed influence on dress code, which depends on many factors including maintaining a professional image, as shown here, or the surrounding urban context, as emerged from a previous study (Healey and Webster-Mannison, 2012); and
- Social practices of cooling as an act of courtesy.

More novel organisational practices, and the use of innovative engagement strategies such as those using 'fun theory', may have the potential to challenge or encourage these types of cultural norms.

4.4 Constructing a comfort norm

The qualitative measure of success for an occupant-controlled, low energy building in a benign climate zone should be whether natural ventilation is accepted as 'normal' and considered as providing a high quality, desirable work environment. Accordingly, active climate control should be seen as a fall-back position – a method of short-term corrective action.

In the study building, occupants established habits in achieving comfort, constrained by the physical comfort zone, of which humidity was an important determinant in summer. It was also constrained by a number of non-thermal factors as outlined in section 1.1. For most occupants, natural ventilation was entrenched as the default setting, heavily influenced by a perception of healthiness. This created a default work environment where adaptations for air movement (windows and ceiling fans) were

often the first preference in enhancing comfort, for reasons of pleasantness as much as heat balance.

5 Conclusion

The results have demonstrated that through an exploratory approach allowing occupants to discuss comfort in their own words, issues which influence the experience of comfort outside of the deterministic relationship can be identified. These included factors of the physical environment, aspects of the social setting, cultural perception, and organisational influence. These factors can either entrench a culture of energy-judicious behaviour, or of one which accepts and expects the unrestrained use of energy. Some, but not all, of the themes emerging from the results can be of use in achieving a user-controlled mixed-mode building which is judged positively by its occupants. Other themes are outside the influence of design and management but nevertheless add richness to understanding of the relationship between the building, its occupants, and comfort.

A study of a single building and a relatively small group of interviewees is not intended to provide generalisable, repeatable data, but rather to explore thermal comfort from a user-centric and qualitative perspective. In-depth analysis of a single building can reveal aspects not possible by mass survey techniques with predetermined scopes. The results, however, are relevant to the experience of occupant-controlled mixed mode in single-person or low-occupancy offices. Further work within this project will present a similar perspective of open plan workspaces and the more complex design challenge that involves. In adopting a loose research structure, the study has revealed avenues for future research.

Most significantly, the results support the increased use of social research methods in building science. This study used interviews which by nature involve reflection and recollection by occupants. Alternatively, in-situ observational techniques could provide a more reliable source of data. Of particular interest are occupant interactions in group decision making for comfort, with attention paid to the influence of user group size, from two-person offices to large open plan. Some interesting characteristics of group negotiations have been identified previously (Healey and Webster-Mannison, 2012).

The results identified at least three particular groups of occupants; those for whom working in the building had altered their values and behaviour in terms of environmental sustainability, those who felt they were already engaged with the issue and showed little further desire to change, and those who were uninterested or ambivalent. These groups may provide an interesting basis for longitudinal study of pro-environmental behaviour in green buildings. In the context of the research interest presented here, such knowledge may assist in better fitting design concepts to specific user groups.

Finally, there is an implied promise to occupants of low energy buildings, particularly those buildings of unconventional design and operation, that the behaviour changes requested of occupants will result in lower energy use. To many occupants, these behaviour changes are seen as compromises. Additionally, when greater responsibility in operating the building is placed in the hands of occupants, they expect the building performance to uphold the same responsibility; to be comfortable, energy-efficient, and to support their functional needs, and without prioritising energy efficiency over comfort or function. Buildings which fail in fulfilling these expectations not only fail

the occupants, they erode industry confidence in mixed mode, occupant control, and other unconventional low-energy design strategies.

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