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Re-contextualizing the notion of comfort

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To what extent can the urgency of climate change and an evolving concept of agency (at the individual and social levels of building users) create a new context for rethinking the notion of comfort? A new, emerging notion of comfort is explored that embraces engagement with new conditions, new experiences, and new types of interactions between inhabitants and building systems and unfamiliar technologies. The emphasis is on communication and dialogue as two dynamic and adaptive processes necessary to achieve optimal building performance while valuing and responding to inhabitant knowledge and agency, and enhancing indoor environmental quality from the standpoint of the inhabitants. A primary conclusion is that the goal of shifting into a lower carbon society has created a new context for comfort, from its conventional emphasis as automated, uniform and predictable, to a broader notion that takes into consideration dynamic, integrated, and participatory aspects. The key dimensions of this emergent broader view of comfort are examined and the relationships between them revealed.

Keywords: adaptive behaviour, agency, climate change, comfort, communication, dialogue, energy demand, indoor environmental quality, inhabitant, occupant, social interaction, sustainable development, workplace

Introduction

A host of physiological, psychological, cultural, behavioural, and contextual factors shape a person’s engagement, experience, and enjoyment of environmental conditions in buildings. Despite an extensive and rich literature on the social and cultural contexts
for human experiences, over half a century of comfort research and comfort provision in the building field has been guided by the search for a universally applicable set of optimum comfort conditions based on a primarily physiological model. In reaction to conventional notions of comfort, Chappells and Shove (2005) suggest that the ‘future of comfort remains fluid, contested and controversial’ and that:

the range of possible responses is much wider than that currently contemplated by energy and environmental policy-makers.

(p. 33)

In this vein, we suggest that a number of current and emerging developments collectively provide a context for revisiting the notion of comfort.

Research related to defining appropriate comfort conditions in buildings has a long history and the purpose of this paper is neither to describe nor to critique this work in any detail; suffice it to say, it has been contained almost entirely within the domain of mechanical conditioning and automated, centralized approaches to control. The intention of the paper is rather to explore the extent to which the urgency of climate change and an evolving concept of agency at the individual and social levels of building users, together with the experience gained from current innovative green building design practices and performance assessment, create a new context for rethinking the notion of comfort. This leads to thinking of comfort in a much broader sense than the conventional view, i.e., the provision and maintenance of a fixed set of thermal, luminous and acoustic conditions.

In what follows, we describe building occupants as ‘inhabitants’, who may play an active role in the maintenance and performance of their buildings, as opposed to ‘occupants’, who are passive recipients of predetermined comfort conditions. The paper explores a notion of comfort that embraces engagement with new conditions, new experiences, and new types of interactions with building systems and unfamiliar technologies. The emphasis is on new responsibilities of communication and dialogue as dynamic and adaptive processes necessary to achieve optimal building performance, and to recognize the role of inhabitant engagement in the comfort process. The dynamic, integrated, and participatory dimensions of this new context for comfort are paramount as designers aim for greater levels of sustainable structures and systems and move away from the more conventional emphases on automation, uniformity, and predictability.

The paper focuses on comfort as evidenced in commercial as opposed to residential buildings. The workplace setting shifts the focus from individual to collective experiences of comfort, thus setting the scene for a broader discussion of interactions, interdependencies, and collective behaviour. Unlike residential building where inhabitants typically have a greater degree of control and can express their comfort needs and desires by adapting their indoor environment more readily, inhabitants of commercial buildings rarely experience extensive control of their environment. Moreover, inhabitants of commercial buildings who feel a greater sense of control and agency with respect to the building environment may also experience a greater sense of comfort.

The paper is organized into five main sections. The second and third sections attempt to capture the shift that has occurred over the past decade or so in the assumptions embedded in the notion of comfort and the practices that either influence or are influenced by them. The second section specifically describes the emphasis and underlying assumptions in conventional comfort research, and how these notions of comfort are interpreted and translated into building design. The third section examines the relevant key developments as evidenced in contemporary practice, in particular: green building design, the integrated design process, post-occupancy evaluation (POE) and performance assessment methods. The fourth section extends the range of influences to include the urgency of climate change and an evolving concept of agency at the individual and social level of building users. Collectively these provide a new context for rethinking the notion of comfort in a broader, more comprehensive manner. The fifth section presents key attributes and potential consequences of this emerging broader notion of comfort, emphasizing dialogue, and communication as a critical overlay to the shifting notion of the experience and provision of comfort.

**Conventional comfort provisioning**

It is widely understood that comfort provisioning and experienced comfort are context dependent (Cooper, 1998; Crowley, 2001; Ackerman, 2002). Comfort provisioning derives from a host of design requirements, priorities and assumptions about building occupants, and the types and costs of available environmental control technologies, while experienced comfort depends on the intersection of technical comfort provisions and the psychological and social realms of experience, movement (mobility) and interaction.

**Assumptions in conventional comfort research and provisioning**

Conventional research and development of comfort provision evolved within a period of technological innovation and the widespread deployment of energy-intensive mechanical systems. This led to a shifting of design responsibility for comfort from architects to mechanical engineering consultants, and
control responsibility from occupants to technology. Within this context, the notion of comfort was guided by several key assumptions:

- That occupants are passive recipients of the conditions provided in the workplace. This assumption formed the basis of early laboratory-based research involving physiological and ergonomic experiments on human subjects (e.g., Fanger, 1970; Hollies and Goldman, 1977). Results from such experimental work have been incorporated into design codes and standards around the world.

- That although psychological and behavioural issues may contribute, the primary mechanism of comfort is physiological. Current definitions of acceptable thermal comfort conditions, for example, have their roots in the extensive research of Ole Fanger, Director of the Centre for Indoor Environment and Energy, Technical University of Denmark. Fanger’s influential comfort equation is physiologically based and contains terms that relate to functions of: clothing (clothing insulation and the ratio of clothed to nude surface area); activity (metabolic heat production and metabolic free energy production); and environmental variables (air temperature, mean radiant temperature, relative air speed and pressure of water vapour).

- That psychological aspects of comfort are individually based, relating to the ‘perception of, and reaction to, physical conditions due to past experience and expectations’ (Bragar and de Dear, 2000, p. 2). Research in this vein has focused on occupants’ health (Raw et al., 1993, cited in Leaman and Bordass, 1999) and thermal comfort expectations (Humphreys, 1976; Brager et al., 2004) with and without access to personal control. A number of studies have been conducted that suggest that the more opportunity occupants have for personal control, the more tolerant they are of their indoor environment (Bauman et al., 1998; Brager et al., 2004).

- That indoor environmental conditions should be held within relatively tight margins. Although it is increasingly recognized that variation in environmental conditions is desirable (Heschong, 1979; Humphreys 1995; Steemers and Steane, 2004), if not essential, the notion of an optimal temperature remains a current design aspiration, whereas both spatial and temporal variances are seen as leading to a degradation in comfort (Baker, 2004). The 2004 editions of ISO 7730 reference Grades A, B and C indoor climates, with those in Grade A being very tightly prescribed, reinforce the dominance of such notions.

- That a globally applicable set of optimum comfort conditions should be incorporated into national standards, which in turn shape and define acceptable indoor conditions for occupancy. Ease of access to information, increased mobility of designers, and the formation of cross-national organizational frameworks and conventions such as those in the European Union have led to a unification of the context for building design.

Conventional practice

Figure 1 shows the approach to comfort provisioning in conventional building design practice where the emphasis is on mechanical and electrical systems and where consultants operate independently from one another.

The scope, emphasis, and requirements for ‘comfort’ deemed appropriate are represented in standards applicable to specific building types and usage. The key dimensions of comfort – thermal, visual, acoustic and air quality – are described primarily in terms of an individual’s physiological and (limited) psychological comfort. These comfort standards serve as a guide for design consultants, and later as a reference for regulatory authorities to assess whether ‘acceptable’ conditions have been provided within the workplace. Comfort standards will be variously interpreted by the respective design professionals in the context of the specific project and the requirements of the client.

The more critical issue is the translation of the generic comfort standards through the choice of specific design strategies that individually and collectively create the context for building operators and occupants. For example, while a number of design strategies may deliver the same prescribed temperature or illuminance, each may offer qualitatively different opportunities to support broader psychological and behavioural aspects of comfort.

The conventional realm of comfort provisioning is the combination of building and systems enveloping the occupants, and the type and extent of the control that is available to building operators and occupants to meet thermal, visual, acoustic and air quality physiological needs. As Figure 1 indicates, the process is a linear one, with the occupant’s physiological (and more rarely psychological) comfort being seen as the result of a series of design decisions. There is little opportunity for feedback from the occupant regarding those design decisions, and still less the comfort standards. The extent to which psychological needs are met depends on the choice of design and controls strategies. Behavioural aspects of comfort are largely ignored, except those that fall under the categories of physiological or psychological, e.g., activity level, clothing, level of personal control. The result is a unidirectional design process where the building occupants are the passive recipients of the outcomes of such research and practice.
Not only has the conventional approach restricted the degree to which the social and behavioural dimensions of comfort have been addressed, but also it has reinforced an approach to building design, management and operation, which is inherently oriented towards considerations of uniformity and predictability, rather than resilience and adaptation. The goal is buildings that perform to a prescribed set of narrowly defined standards, independent of the dynamic of inhabitants. The possibilities for a more interactive approach, in which the occupants are directly engaged in the design and management of the building’s systems, have tended to be overlooked. Permitting occupants a higher level of control is perceived as a risk that could diminish building system optimization and increase building owners’ and management’s economic and labour costs were occupants to make uninformed and thus wasteful decisions.

Emerging practice and directions

While many of the assumptions and approaches raised in the second section still persist, several developments have occurred in design and building professions over the past decade that have begun to influence the notion of comfort and comfort provisioning.

Green buildings

Green buildings aspire to far superior environmental performance compared with their conventional counterparts. Many green buildings rely on natural conditioning to meet the comfort needs of inhabitants. The term ‘inhabitant’ is used from this point on to capture more accurately the active participation and potential agency of building users with building systems than the term ‘occupant’ used in conventional comfort research to portray a passive recipient of universalized comfort standards.

In naturally conditioned buildings, the following conditions occur:

- interior comfort conditions are provided primarily by a combination of ‘passive’ strategies such as thermal mass, passive solar heating, passive cooling, natural ventilation, and daylighting
- interior conditions are more closely linked to daily and seasonal variations in conditions outside, and thus see greater variation than interior conditions in conventional buildings
- building inhabitants are more directly involved with building systems and operation by opening and closing windows, blinds, switches and other accessible manual controls

Energy and water systems employed in green buildings, such as green roofs, energy-efficient equipment and policies, sustainable transportation, composting systems, etc., may involve new responsibilities and require a commitment from inhabitants to engage with positive environmental practices.
In addition to generating a host of environmental benefits, green design strategies also offer the potential to reinforce what Wilson (1984) called ‘the instinctive bond between humans and other living systems’ or as Kellert (2005) describes biophilia as ‘the inclination to value nature’. Biophilia is a growing and important recognition that human experiences of comfort and space are strongly influenced by one’s biological and evolutionary history. Thus, the psychological dimension of comfort is expanding from the provision of personal control to the include provision of daylighting, views of the outdoors, direct contact with nature, natural materials, etc. (for example, Heerwagen, 1998, 2003).

The successful performance of green buildings, particularly where passive strategies are deployed, is largely dependent on variation and diversity in environmental conditions. The indoor environment can be considered a ‘creative achievement’ shaped by the interaction of building inhabitants with control systems in response to changing external conditions and the changing needs of inhabitants. From a comfort perspective, this suggests the need for a shift towards a broader experience of comfort that takes into account dynamic and participatory aspects.

In 2006, the US Green Building Council’s (USGBC) Cascadia Chapter issued a ‘Living Building Challenge’ to building owners, design professionals, engineers and contractors that embraces – and to a degree necessitates – the notion of participatory comfort. Based solely on prerequisites rather than a credit system, the Living Building Challenge aims to transform current approaches to sustainable design and construction, providing models for the future. The Kenton Living Building, a residential building with a daycare centre in Portland, Oregon, is striving to become the world’s first certified living building by attaining all 16 prerequisites including ‘net-zero’ energy and water consumption. Tenants will be required to be more involved with the building than tenants in conventional buildings, with specifications of their inhabitant–building relationship written into their lease. Each inhabitant will have a daily water limit and a personal energy budget with a digital system displaying overall energy use and generation to the public (Zemtseff, 2007). The project illustrates a growing recognition of the need to engage social and behavioural dimensions of comfort, as well as the potential of improved dialogue and communication to enable adequate building performance. Though some dimensions of comfort that rely on accessible and abundant resources (e.g., hot water available at the turn of a tap) are compromised by the tenant agreement that limits resource use, a substantial leap in environmental control over conventional residential units allows tenants of the Kenton Living Building the freedom to exercise their judgement and establish their personal comfort standards to a much greater degree. A high level of engagement with the sustainability principles and practices of the building system results from the tenant’s agreement, paired with a high level of interactivity and investment performed on a daily basis.

Integrated design process
The successful integration of environmental systems and strategies, as described in the previous section, requires transcending professional boundaries and working towards a comprehensive, team-based approach known as an Integrated Design Process (IDP). IDP has emerged as offering a profoundly different approach to building design than linear convention would dictate. During an IDP all the players responsible for design and construction – architects, landscape architects, engineers, cost consultants, construction managers, etc. – work together as a team from the outset. Through consensus, a multidisciplinary project team can use their specialized knowledge to create comprehensive strategies for a project, and enhance communication among otherwise unfamiliar parties. This process allows participants to establish performance goals and a vision for the project that is understood and supported by everyone. Such goals can serve as the basis for a design process based upon an integrated analysis of how different building systems can work together and thereby identify synergies among structural, mechanical and electrical systems that are conventionally designed in isolation.

IDP shapes the new context for inhabitant comfort in that it offers the potential of improved dialogue between members of the design team, thereby about short- and long-term consequences of exerting environmental control, enabling various views of inhabitant comfort and their consequence for building inhabitants to be openly debated. Moreover, the greater levels of system integration resulting from IDP enable explicit discussion on the potential consequence for building inhabitants’ comprehension and engagement.

Performance assessment
Building environmental assessment methods, such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM), have institutionalized the need to assess building environmental performance across a broad range of performance metrics, including indoor environmental quality. They have profoundly influenced the way that building environmental performance is communicated (Cole, 1999) by requiring greater dialogue and interaction between members of the design team and various sectors of the building industry. The language afforded by performance assessment has led to increased communication and feedback among designers, industry,
government, and end users around what are to be considered sustainable, comfortable, healthy and desirable indoor environments. Three important developments have consequence for this paper:

- Assessment methods for new buildings currently evaluate performance immediately after the design/construction and, as such, often only represent predicted or anticipated performance. Experience with POEs is driving interest in performance-based assessment which, by necessity, will require measured data from the case study buildings that have been acquired for a minimum of one full year of occupancy, thereby delaying the issuing of the performance label. The latest release of USGBC’s LEED-NC (v2.2) allows the credit for thermal comfort verification to be achieved by conducting a post-occupancy occupant satisfaction survey as an alternative compliance path to meeting the American Society of Heating, Refrigerating and Air-Conditioning Engineers’ (ASHRAE) Standard-55.

- Performance assessment will also require the declaration of a clear set of absolute performance indicators. While these are available for many environmental performance issues (e.g. ecosystem health, engine emission standards), they do not exist for the full range of issues in current building assessment methods, particularly in the realm of indoor environmental quality.

- There are emerging signs of a shift from simply providing assessment and certification to providing a value-added building performance management system to owners and managers to support continuous performance improvement. This ongoing engagement with buildings over time rather than a single assessment raises a host of new possibilities that take account of the various changes in occupancy over the life of a building.

**Post-occupancy evaluation (POE)**

Following on from IDP, and incorporating the same values of dialogue and communication, POE – the systematic evaluation of building performance and/or opinion about buildings in use from the perspective of the people who operate and/or inhabit them – has earned increasing attention and application in recent years, particularly as applied to green buildings. It is widely known that building performance in use often differs markedly from that anticipated or predicted during design. According to a 2007 study by the New Buildings Institute, 30% of LEED buildings perform better than expected, 25% perform worse than expected, and a handful have serious energy consumption problems post-occupancy (Owen et al., 2007).

This performance gap results not so much from the building design and technology itself, but rather from the differences between assumed and actual patterns of occupancy, the use of controls, and building operation and management. Based on a wealth of experience in evaluating actual building performance, Bordass and Leaman (1997) point to overly complex building systems as a major deterrent for efficient and effective building operation (also Bordass et al., 1994). Their work suggests that since high-technology buildings are relatively complex to operate, dedicated management is essential if they are to achieve optimal performance. The findings speak to an underlying irony in that well-designed, technically sophisticated buildings are intended to reduce, and not add to, complexity. In a similar vein, the operation of a low-technology (i.e., passively ventilated or heated) building may also not be optimal, simply because the operator and inhabitants may not understand passive systems and their role in system management.

To enable inhabitants to identify and resolve operational problems, building systems must be readily accessible and comprehensible to building users and clearly accompanied by a willingness to use them. A key lesson is that the environmental success of a building depends on matching technological and management sophistication. As Cohen et al. (1999, p. 2) observe from their Post-Occupancy Review of Buildings and their Engineering (Probe) studies, the:

> challenge for designers and manufacturers is to support [the inhabitants] with appropriate and understandable systems with readily usable control interfaces, which give relevant and immediate feedback on performance.

The communication of responsibility can be increasingly observed – particularly in green buildings, in the form of instructional signage (e.g. EduTracks1), exposed and experiential building systems, and real-time feedback on building performance and the consequences of occupant interaction (e.g. GreenTouchScreen2 and Building Dashboard3). This recognition of individual and collective inhabitant agency (and not solely of the agency of building managers or designers):

- places the responsibility of conscientious management in the hands of all inhabitants
- creates a context for innovative approaches to enhance trust and a sense of collective responsibility for the building’s performance
- can create new problems to the degree that this greater responsibility is resisted or frustrated by the complexity of these new building controls and management systems
Higher degrees of responsibility that depend on inhabitant agency clearly also have implications for psychological, behavioural and social dimensions of comfort.

**A new emphasis and approach to comfort**

The current practice of comfort provisioning has been characterized in the third section as a contested field in which the legacy of conventional assumptions intersects with progressive expectations of green performance. There is an increasing recognition of the need to move beyond physiological comfort and more considered acknowledgement of users and their engagement with controls and other building environmental features that is sufficient to recontextualize the notion of comfort. However, before doing so, it is necessary to acknowledge two additional factors: climate change, which adds a sense of urgency, and agency and complexity, which provide a new lens through which to view the challenges ahead.

**Climate change**

The building sector has been identified as a key potential contributor to efforts to mitigate climate change (Metz *et al.*, 2007; Ürge-Vorsatz *et al.*, 2007a, 2007b). However, it is difficult to imagine the required transformation of the built environment will result from simply tweaking current practice. Instead, substantial leaps in building performance will be required over the next several decades. This will have significant implications for conventional approaches to comfort and, depending on the strategies employed, provides further impetus to redefine and broaden the scope of what building inhabitants consider 'comfortable' indoor environments.

Given the imminent reality and urgency of climate change, buildings will now increasingly need to be designed to do the following:

- produce significantly less, or no, greenhouse gas emissions
- adjust to changing outdoor climatic conditions
- engage inhabitants in adapting to changing indoor environmental conditions

In addition to those approaches discussed in the third section, the process and strategies employed to achieve these goals reinforce a shift towards a broader experience of comfort that takes into account dynamic (adaptive) and participatory (social and behavioural) aspects. In light of climate change, Chappells and Shove (2005) raise a number of opportunities for behavioural and technological changes that promote adaptive comfort standards:

- Instead of expecting standardized conditions indoors all year round, people may become used to greater seasonal variety thus permitting seasonal fashions to provide an important means of managing climatic variation.
- New clothing technologies could be developed to provide for insulation and environmental control, taking the pressure off the managed indoor environment.
- Institutional flexibility that includes variable work hours (e.g., vacating the office during the hottest hours of a summer afternoon), and flexible dress codes that allow for seasonally appropriate clothing options may become normalized to the point that designers can depend on inhabitants to participate in indoor comfort provisioning (Morgan and de Dear, 2003).

The collective social and institutional renegotiation of ‘normal practice’ is a real possibility in the changing context of new design. Designers would still produce buildings that require heating and cooling, but only by as much as is required to maintain indoor temperatures within a much expanded range. Inhabitants would still expect some level of thermal stabilization from buildings but could adapt their clothing and schedules to decrease the heating or cooling loads on building systems, thus participating in the building’s system optimization.

**Agency and complexity**

An integrative and participatory process is one that considers the relationships between inhabitants, and between inhabitants and building systems as interactive and multidirectional, not linear or predictable as is assumed in the conventional approach. Human agency adds a level of uncertainty and unpredictability that conventional comfort studies have attempted to minimize by designing and implementing systems that either eliminate the need for human intervention due to increasingly high levels of automation or dictate permissible occupant actions under pre-set conditions. Managing occupant agency as a perceived risk to building systems indicates that conventional designers view the uncertainties inherent to human agency as a destructive force. The alternative is to view human agency:

as an advantage and not just a weakness – it is the means by which we manage risk and take advantage of opportunities by deviating from business as usual.

(Jones, 2004, p. 32)
As a founding figure of the sociology of human agency, Habermas (1989) outlines his optimism of human capacity for positive change, or constant improvement. In his theory of communicative action, Habermas claims that contemporary society is experiencing a decreasing rate of positive change, perhaps even a reversal, that is precipitated by a high level of structure and thus a restriction on human improvisation. Improvisation occurs under new circumstances for which there is ‘no set response’ (Holland et al., 1998). Improvisation creates space for new expectations and dispositions to emerge, but it does not occur in a vacuum. French social theorist Bourdieu (1977) describes a ‘field’ of social and cultural structural indications and limitations in which human actions, including improvisation, occur. Similar to aesthetic change that occurs in the professional field of design over time, socio-cultural change occurs slowly and relies on moments of ingenuity that point to new directions of interest. Human behaviour continuously (re)produces the social structure experienced, within which change can occur as individuals and groups express agency (Giddens, 1984). To increase a building’s resilience to climate change over time designers should work with the understanding that their role is, in part, to provide the technologies, controls, and information (the structure) within which inhabitants choose their actions and potentially devise new strategies to address changing conditions and needs (improvisation).

On a large scale, when designing systems where people are permitted to express agency:

we must allow for a multitude of outcomes, participants with different goals, bifurcations, sheer bad luck and utter serendipity.

(Jones, 2004, p. 14)

Gunderson and Holling’s (2002) panarchy concept provides a viable framework for preparing for the unpredictable in scenarios of human and natural system evolution. Green buildings and building inhabitants are complex adaptive systems that must be resilient, that is, flexible and responsive, in the face of climate change to survive and remain sustainable.

In traditional comfort studies the strong emphasis on technical standards and applications that produce automated services with reduced control mechanisms obscures the adaptive social dimension of comfort. Human agency and identity are experienced not only at the individual level, but also at the collective level of social interaction. Agency and identity are co-developed among members of a group and evolve as the group itself or its needs evolve (Holland and Skinner, 1997). The meaning of things is also constructed collectively and:

collective meaning systems are situated in social action, education, and individual development as they occur in practice.

(Holland and Skinner, 1997, p. 193, original emphases)

However, knowledge of how people understand the world and collectively create meaning through action has to date had little effect on comfort research and provisioning. A programme for social engagement with a building system must parallel the design and building programmes, providing space for inhabitants to express their understanding of the system and any additional needs they require when making adaptive decisions.

Contemporary design can shape a new context of comfort to address active inhabitants who respond to environmental conditions, adapt, and work with system controls to adapt the system to his, her, or their own needs. This suggests a reorientation of the approach to comfort in which the goals and objectives of the building systems and the inhabitants are equally engaged and equally attended to. A complex web of heterogeneous interdependencies thus replaces the conventional approach that values the optimization of building systems above the complex and changing needs of inhabitants. Feminist theorist Harraway (1991) analyses cultural–technological interfaces (i.e., inhabitants interacting with building components) as productive of cyborg entities: the result of a human–technology interaction is a hybrid being who is neither human nor machine but has unique and sometimes unexpected characteristics. Dynamic, adaptive building systems that respond to a changing climate and require inhabitant engagement for optimization are prime examples of this hybrid nature. A necessarily complex dialogic relationship exists between the inhabitant(s) and the building where both the human and technological components have and express agency.

Figure 2 illustrates the ways that climate change and agency-and-complexity together form a new lens with which to view emerging design and construction strategies (green building, integrated design POE, performance assessment) that affect inhabitant comfort.

Recontextualizing comfort

Figure 3 illustrates the emerging expansion of the notion of comfort. The issues highlighted stand in contrast to currently held notions of comfort and the manner in which comfort is evidenced in conventional practice in Figure 1. In particular, Figure 3 acknowledges that comfort research and provisioning must move beyond physiological comfort substantively to address the psychological, behavioural, and social
(or collective) drivers of inhabitant comfort. A building and inhabitant system that aims for interactive adaptivity values those drivers and has the flexibility necessary to adapt to the changing needs of the entire system over an extended time.

Moving beyond physiological comfort
Whereas the physiological dimension remains a primary consideration in conventional approaches to comfort, psychological and behavioural comfort take on greater significance in the expanded approach.
These factors (cultural, psychological, behavioural, social and contextual) layer and interact to determine a person’s engagement and enjoyment of prevailing environmental conditions.

For example, recent research by de Dear and Brager (2001) substantiates the widely accepted idea that people can be satisfied with a much greater range of thermal conditions than Fanger’s theory predicts. Their work is based on a detailed analysis of extensive thermal field data from 160 air-conditioned and naturally ventilated office buildings around the world. In air-conditioned buildings, occupant preferences followed close agreement with those predicted by Fanger’s predicted mean vote (PMV) thermal comfort model, regardless of climatic context. For occupants of naturally ventilated buildings, however, those in warm regions favoured indoor temperatures that were significantly warmer than those preferred in cooler climate zones. De Dear and Brager interpreted these findings:

as evidence that the occupants of the free-running buildings were adapting behaviourally and psychologically to the varied indoor climates driven by external weather and seasonal cycles.

Moreover, in these buildings:

the wide range of preferred indoor comfort temperatures was strongly influenced by shifting thermal expectations, most likely resulting from a combination of higher levels of perceived control, and a greater diversity of thermal experiences in the building.

In contrast to the occupants in naturally conditioned buildings, those in buildings with air-conditioning were adapting to constant and narrow temperature ranges, and indeed were becoming ‘addicted to homogeneous and static indoor climatic regimes’ (Brager and de Dear, 2003, p.189).

Behavioural issues are, to some extent, evident in current comfort models by accounting for activity and clothing variables, but these are now expanded to include the ease with which inhabitants can make individual adjustments to the environmental conditions in their workplace, as permitted by a range of formality in dress codes, flexibility of workstations, enhanced mobility afforded by laptops, plug-and-play technology, Personal Digital Assistants (PDAs), etc.

However, while inhabitants may be the best measuring instruments, they are the hardest to calibrate. Leaman (1999) presents a set of ‘real’ building–user interactions with environmental controls that stand in marked contrast to those typically assumed in design. Occupants, he notes, tend to make decisions to use switches or controls only after an event has prompted them to do so (rather than in advance of it) and often wait for some time until taking action, typically acting only when they reach a ‘crisis of discomfort.’ Moreover, they can overcompensate in their reactions to relatively minor annoyances, operate the most convenient rather than logically appropriate controls and leave systems in their switched state rather than toggling them back again later, at least until another crisis of discomfort is reached. Thus, placing responsibility for comfort conditioning in the hands of building inhabitants necessitates a shift in the quantity and quality of understanding and communication about the short- and long-term consequences of exerting environmental control.

The Philip Merrill Environmental Center, the first LEED Platinum building in the US and home to the Chesapeake Bay Foundation, is an example of a building communicating environmental control to inhabitants in a meaningful and innovative fashion. Described as a ‘social experiment as well as an environmental one’ (Heerwagen and Zagreus, 2005, p. 3), the entire workforce is arranged in an open-plan setting, disregarding rank or position. Shared areas with low partitions are intended to promote social interaction as well as provide equitable access to daylight and views. The building is naturally ventilated, employing sensors throughout to monitor temperature and humidity, and alerting occupants through indicator signs when conditions favour opening windows for natural ventilation. A POE conducted by Heerwagen and Zagreus (2005) revealed the highest level of air quality satisfaction (at the time) in the database of the Centre for the Built Environment, University of California, Berkeley. Occupants reported a strong sense of pride in the values conveyed by the building, as well as social benefits including improved communication, sense of belonging, and feelings of being treated in an egalitarian manner.

Shifting the focus beyond individual comfort

Social comfort, as used in this paper, relates to the relationships between inhabitants and includes issues of adjacencies of workplaces and sense of territory, status associated with open and closed offices or proximity to windows, privacy and communication, opportunities for interaction, sense of collective agenda, etc. Additionally, social comfort refers to the phenomenon of collective understandings of experienced comfort and the co-development of agency for achieving comfort.

Similar to mechanically conditioned spaces, many green building strategies essentially and explicitly rely on shared comfort and control in order to achieve environmental objectives. The prescription of appropriate indoor environmental conditions invariably
leads to the awareness that individuals have different comfort needs and experiences of comfort change again when individuals gather as collectives. As a result, group dynamics and interactions clearly influence the success of green building systems and inhabitants’ adaptive strategies. Culturally, certain expectations and tolerances become established, embedded and expressed in comfort metrics, and in turn these expectations and tolerances become embedded in workplace subcultures.

In this new context, social dynamics within the workplace become an explicit consideration in the definition and experience of comfort. The collective understanding of what is ‘comfortable’ can affect individual understandings of comfort, just as every individual arrives with a set of personal comfort standards that feed into the collective understanding. Some level of personal comfort may be compromised consciously or unconsciously for the greater good of collective comfort. Personal technologies and strategies for comfort may reinforce the comfort of others, like dressing in removable layers; or compromise the comfort of others, such as wearing perfume that affects the local air quality, or blocking daylight and views with furniture and moveable walls.

Over time, inhabitants develop a working knowledge of building structural and system mechanics that is shared between co-inhabitants in the form of common grievances, or tips for how to find comfort within the building. In this way both knowledge and preferences become shared – collective understanding and collective expressions of preference (i.e., comfort) feedback to contribute to individual experiences of comfort. Experiential knowledge informs building management about the comfort requirements of inhabitants in the form of complaints and service requests, and more subtly as inhabitants choose to occupy some areas of the building and avoid other areas where drafts, leaks, noise, or fumes disturb the comfort and the productivity of inhabitants.

### Interactive adaptivity

The new conceptualization of comfort points to new directions for communication and dialogue occurring at all stages of design and occupancy, culminating in interactive adaptivity. A dynamic and complex building system with a participatory process, interactivity between inhabitants, and between inhabitants and building elements can adapt to changing conditions (e.g., seasonal temperature change, or, on a larger scale, global climate change), resulting in a fluid but robust design that is responsive to social, ecological, and economic conditions over time.

A necessary correlate to interactive adaptivity is open communication and dialogue between all the

### Potential challenges and friction

Unlike conventional centrally and mechanically controlled buildings, the performance of naturally conditioned buildings is ‘not a foregone conclusion’ (Shove, 1995, p. 164). Challenges and potential frictions accompany any major transition; the transition to a lower-carbon society will similarly not occur without tension and some resistance. Leaman (2003, p. 166) illustrates that naturally ventilated buildings can be highly successful in occupant satisfaction, particularly:

where there is simple, good and effective user control, even where the conditions are objectively less good than in many air conditioned environments.

On the other hand, conditions can be ‘dreadful’ in ‘over stressed’ naturally ventilated buildings such as...
those that have overly deep plan forms, are too densely occupied or have ‘idiosyncratic user controls’. Caution must be exerted in pairing passive design strategies with sympathetic spatial programming in order to avoid a situation that could potentially detract from the energy-saving advantages of passive design, or negate the advantage of inhabitants perceiving the building to operate on nature-like systems and flows (i.e., leveraging biophilia as described above).

In more serious situations, unless all occupants make appropriate and intelligent choices, the safety and security of the inhabitants and the building itself may be compromised. This raises questions regarding the extent to which inhabitants can be active participants in an interactive, adaptive model of comfort provisioning. Are emerging high-performance buildings actually being designed with inhabitant engagement and intelligence in mind? How successful are building information sessions, user manuals, ‘green’ features signage and sustainability pledges in instilling individual and collective commitment to, and engagement with, positive environmental practice? Moreover, what is the appropriate balance between strategies aimed primarily at informing inhabitants and encouraging feedback about appropriate control settings, and those that encourage more active forms of physical engagement with controls and monitoring systems? And what are the performance implications of de-automating key building systems? These questions require more extensive research premised on the added value of inhabitant interaction and responsibility for building system optimization and, simultaneously, inhabitant comfort.

Research indicates the importance of creating feedback mechanisms about environmental performance, e.g. real-time energy use, to transfer knowledge and influence inhabitant behaviour. In residential settings, feedback has been shown to play a significant role in raising energy awareness, bringing about reduced consumption of the order of 5–15% (Darby, 2006). In collective settings such as the workplace, where inhabitants are unlikely to bear the costs of building utility bills, feedback mechanisms and their ability to change behaviour may be fundamentally different. The specific manner in which building environmental strategies are communicated may be important in nurturing a more fundamental shift in building design to address the environmental agenda. However, many questions must be answered before designing communications to ensure the communication is adequate and effective including identifying what green features and strategies most effectively communicate pro-environmental messages to inhabitants and the wider public.

The establishment of indicators that are meaningful and relevant to designers, building managers, and inhabitants is an essential step that requires a full understanding of the complex nature of the building system and the social and cultural dynamics of the inhabitants (Moldan et al., 1997). The evolution of information technology over the past two decades has provided building systems with an increasing capability to measure, evaluate, and respond quickly to change. As Kell (2005) argues, the challenge of intelligent buildings is to make the best use of available information, with the understanding that:

> which information, what performance, and how value is measured depend upon the viewpoint of the specific advocate.

(p. 5, added emphasis)

How much and what kind of information is valuable to inhabitants (i.e., energy use, water use, material flows, real-time comfort conditions, simulation capability, processes for discussing or modelling alternative behaviours) and how and to whom should it be delivered are questions that should be addressed in a transparent, multi-stakeholder process in which participants gain an understanding of the complexity of the system and the ‘interconnections among actions and outcomes’ (Beratan et al., 2004, p. 184).

![Bi-directional interaction of building systems and inhabitants](image-url)
If inhabitants of green buildings are increasingly expected to demonstrate adaptive capacity to environmental conditions and systems, educational and psychological support must be in place to ease the transition from their prior experience, which would typically be based in more automated and tightly control conditions. Researchers must investigate whether there is a potential trade-off between building performance with respect to environmental goals (e.g., energy use) and the social dimensions of comfort (e.g., greater satisfaction from more control over building systems) and, if so, clearly communicate the trade-off in an open dialogue with inhabitants.

A common thread in much of the preceding discussion had been an increasing recognition and enhancement of communication and dialogue in a number of areas related to building design, operation and inhabitation. Figure 4 conceptually illustrates this deeper form of interaction between building inhabitants and building systems, and, over time, with the building design process. The key is that communication and interaction are bidirectional, where the inhabitant experience of comfort and the building systems’ performance depend on a form of ongoing dialogue in which the outcome is not predetermined by building design parameters or performance metrics. Instead, there exists a kind of adaptive dance in which both the inhabitants and the building they occupy gradually approach mutually satisfactory outcomes.

Conclusions

It is unlikely that the improved environmental performance necessary to reduce greenhouse gas emissions significantly will be achieved by technological solutions that do not challenge currently accepted design norms or inhabitant engagement. A key issue will be the willingness of building inhabitants both to accept and engage in green building strategies, and the extent to which such requirements are recognized, acknowledged as advantages, and successfully accommodated for by design professionals.

This paper has explored how a host of current issues and practices – green building design and the passive strategies deployed to achieve comfort conditions, integrated design, POE, performance assessment, and levels of inhabitant agency and system complexity – may provide a context for revisiting the notion of comfort in light of climate change and a low-carbon society. These issues and practices, individually and collectively, have raised a new set of requirements and processes including feedback, dialogue, communication, and adaptation. In contrast to previous notions of comfort that centre on individual physiological comfort and view occupants as passive recipients of a provided set of thermal, luminous, acoustic and air quality conditions, the consequences of these factors support the broadening of the notion of comfort and comfort provisioning that considers them bidirectional and interactive. The implications for building design and operation include the following:

- power and control: who is in charge of the process, who decides, etc.
- adaptability: flexible design, modular workspaces, adaptable inhabitants, etc.
- controls, sensing and monitoring at the building and inhabitant levels
- operation of building management systems
- communication and feedback mechanisms
- inhabitants’ interaction with each other, with building managers, and with the building itself

While individually these notions may not be new, collectively and in the context of rapid climate change, their deployment takes on new meaning and urgency. The authors believe that these issues and the new context of comfort described herein represent an exciting frontier for building research and practice.

References


Endnotes

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3Building Dashboard (http://www.luciddesigngroup.com).