Interdisciplinary perspectives on building thermal performance

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Abstract

The performance of buildings remains topical, but in many current conversations definitions of 'good performance' are taken for granted. Building performance evaluation tends to be dominated by studies of how buildings behave with reference to technical standards. However, past studies show that perceptions of good performance are based on broader understandings of what buildings offer, often augmented by interpretations emerging from historical social practices and cultural context.

This paper considers different approaches to describing thermal experience as one way to explore what is meant by 'performance', arguing that just as the social sciences have enriched earlier approaches to describing relations between people and the thermal environment, there are benefits to embracing humanities-based approaches to describe thermal experience. Architectural theory is replete with examples of a deliberate focus on environmental aspects, but its methods and concepts rarely cross the line from ideation to evaluation. This paper disrupts current notions of building performance evaluation by positing alternative perspectives of how people experience buildings. It discusses how current methods might co-exist with phenomenological insights in 'thick descriptions' of how buildings 'perform' and considers possible contributions from modes of inquiry in the humanities to describe thermal experience, illustrated by authors' research in housing.

Introduction

Building Performance Evaluation (BPE) remains topical, with increasing emphasis on securing value for money and satisfying the expectations of clients and building users. It is still largely a technical exercise having developed from post-occupancy evaluations (POE) in the 1980s (Preiser and Vischer, 2004) consisting of measurements of various physical parameters supplemented by satisfaction surveys of occupants. While its popularity may have wavered in the intervening period, it has flourished over the past decade in the UK mainly because of an interest in meeting emerging CO2 reduction targets. The upsurge of interest in evaluation studies is manifest in significant investment in research programmes from the Technology Strategy Board (TSB, now Innovate UK) (Palmer et al, 2016), new educational programmes for built environment professionals, and a focus in the construction industry on the 'performance gap' between desired and predicted performance and measured or actual performance in operation (Sunikka-Blank and Galvin, 2012; de Wilde, 2014; Gupta et al, 2015).

The focus of performance evaluation has shifted since the 1980s. Back then, although energy consumption was a concern following the oil crises of the 1970s, poor building performance often referred to visible degradation of the fabric, such as structural cracks or rising damp (Ransom, 1987; Richardson, 2000; Carillion Services, 2001). With improved building practices informed by extensive technical studies, failure is now more likely to refer to complaints from occupants about unsatisfactory environmental conditions and the putative effects these may have on their well-being or productivity (Vischer, 2007; Bluyssen, 2009). And with rises in the general standard of living, inhabitants' expectations of conditions in modern buildings are higher (Chappells and Shove 2005). While the quality of inhabitants' experience in buildings is now recognized as important to assessing building performance, inhabitants' behaviour is also seen as a significant influence on how a building performs (Stevenson and Leaman, 2010). Thus, people are now recognised as active creators of their environment not simply as passive recipients of conditions created by buildings and their technical systems. Following the lead from Cole (Cole, Brown et al., 2010) we distinguish those two roles by using the terms 'occupant' to denote passivity and 'inhabitant' to reflect agency, but recognise that they are never mutually exclusive.

In everyday practice, the concept of 'performance' and definitions of 'good performance' are taken for granted and rarely considered problematic. Discussions tend to be dominated by technical understandings of how buildings behave with reference to agreed standards. The existing methods and tools are good at telling us what happens in buildings and in quantifying various aspects of measurable performance. While some of the methods consider human aspects, these methods do not aim to explain why inhabitants feel or behave as they do. Without that kind of understanding it is difficult to propose solutions for poor performance or to design future buildings that will address human concerns about performance.

Architectural criticism routinely considers the kinds of experience buildings can and should offer those who inhabit them, but rarely intersects with contemporary paradigms of BPE. When it does, the need for integrating these disciplines is highlighted as a means to explore the complex relationships between people and environment (Preiser, W et al, 2015). However, the buildings that are analysed critically by architectural theorists who are sympathetic to environmental concerns tend to be rarefied examples of architecture remote from examples of mainstream architecture. Few examples of architectural criticism include quantified analysis. Similarly, those engaged in everyday BPE see little advantage in considering what appear to be aesthetic concerns as part of their remit. However, theories of performance that neglect wider concerns of the experience buildings create for their inhabitants are at risk of missing important determinants of people's satisfaction with the buildings they encounter and the influence this has on how they use the buildings. The premise of this paper, therefore, is that a dialogue between natural sciences, social sciences and the humanities can improve the systemic performance of buildings. In other words, how people experience and interact with the thermal environments and the implications for the investigation of energy use and the application of BPE methods.

The purpose of this paper, therefore, is to disrupt current perceptions of 'performance' by offering different perspectives on how people interact with buildings to see what they can offer debates about performance such that we might better understand not only why buildings perform the way they do but also how they might be designed to offer their inhabitants better experiences. This approach is inspired by the work of Ray Cole and others not just on the cultural aspects of thermal comfort (Cole, Robinson et al., 2008) but on his continuous engagement and questioning of how to evaluate building performance (Cole, 2005).

The paper is structured as follows. It begins by examining different definitions of performance and how the word means different things to different stakeholders and depends also on context. Some of these meanings are embedded in legislation. It then discusses experiential approaches to building performance to highlight how propositions from the humanities can enrich the understanding about performance in everyday environments. The paper concludes by discussing the extent of humanities-informed BPE to enhance proposals for better performance in operation and as a tool for designers to learn/reflect from buildings in operation.

Building performance evaluation (BPE)

Before the energy crises of the early 1970s, the performance of buildings referred primarily to their structural integrity, constructional soundness (keeping out the rain, cold and damp) and providing satisfactory environmental conditions – heat, light and sound – focused on minimum standards. Since then, the performance of buildings in practice has increasingly focused on energy consumption and environmental sustainability and is measured against definitions that are enshrined in various standards including national building regulations, and assessed at different stages of the building lifecycle process using proprietary tools, such as BREEAM, LEED, Passivhaus and BUS. The methods often borrow definitions and targets developed to assess specific aspects of performance: thermal comfort, heat loss, lighting levels. In some cases they were originally intended to predict performance before the building is constructed rather than when it is in use. However, as interest in in-use performance has grown, operational versions have been developed, e.g. BREEAM in-use (BRE, 2015), and LEED Operations and Maintenance (USGBC, 2017). However, even when the emphasis is on the operational aspects rather than prediction, the evaluation usually focuses on the energy side of the equation rather than on thermal comfort, thus reflecting the interests of the building owner in reducing running costs and the broader societal interests in reducing energy consumption or CO_2 emissions.

The definitions of building performance articulate how the building should work in terms of measurable outcomes (Foliente, 2000). Performance-based specifications refer to explicit requirements that do not prescribe the specific strategies or means to achieve the goals (Gibson, 1982; Lutzkendorg and Speer, 2005). The performance-based approaches define building targets as functional requirements without specifying solutions (Gibson, 1982) so as to deliver innovative products that represent the best value for money (Sexton and Barren, 2005).

The Energy of Building Performance Directive (EPBD) stipulates that:

'The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs'[1].

The European Union (EU) member states propose the requirements and the verification procedures appropriate for a specific country. Only 10% of EU countries check the actual energy consumption in use (Roelens et al, 2016 p.77).

In England and Wales, The Approved Document Part L Conservation of Fuel and Power outlines the energy performance requirements in buildings (*HM Government 2014*[2]). Compliance requires meeting a target CO2 emissions rate and a target Fabric Energy Efficiency –the latter applicable to domestic buildings. Compliance is demonstrated by comparing a notional building to a modelled building (Criterion 1). Part L recommends the thermal performance of the building envelope to avoid heat losses (Criterion 2) and the expected performance of the building systems (Criterion 4). Provisions are required to mitigate the risk of overheating (Criterion 3). In order to facilitate the 'appropriate' use of the building as expected by designers, guidance and users manuals should be available the building occupants (Criterion 5). In England and Wales, the energy performance of buildings is estimated by as-designed and as-built models. No compliance verification is required during operation.

In spite of the merits of performance-based regulations in protecting innovation, their effective implementation can be deterred by the asymmetry of understanding and information among stakeholders involved in the building lifecycle - clients, designers, building control authorities, regulators (Duncan, 2005). The Construction Industry Board advocates for performance-based approaches to consider the maturity and rigour in criteria and verification systems to satisfy the regulatory aims and the clients' expectations; especially in situations where there is no focus on overall performance but rather minimum

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[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast) Annex 1 *Official Journal of the European Union*, L153/13. Retrieved March 2017 from http://eur-lex.europa.eu/legal-content/EN/TXT/ HTML/?uri=CELEX:32010L0031&from=EN, annex 1.

compliance (Meacham et al, 2005). Hence, building performance evaluation, as a verification method, has the potential to contribute to the effective implementation of performance-based approaches.

The BPE is the process of measuring the extent to which a building meets its targets (BSRIA, 2015a). It combines a suite of systematic and rigorous methods to investigate, measure, compare, evaluate and give feedback to different stages of the building lifecycle from inception to demolition (Mallory-Hill et al, 2012, p3). It is referred to as a PoE when it focuses on the assessment of buildings in operation. For buildings in use, the evaluation includes the technical aspects (i.e. energy consumption, indoor environmental conditions) as well as the factors related to organisational and occupant performance such as productivity, satisfaction with indoor environmental conditions, and health (Zimring and Rosenheck, 2000; Preiser and Vischer, 2004). Mallory-Hill et al (2012) draw attention to the integration between the technical and the occupant factors "to investigate the relation between design and technical performance of buildings in relation to human behaviour, needs and desires [...]" (Mallory-Hill et al, 2012). The BPE can be applied for different purposes: to fine-tune buildings, to inform and justify investments and interventions, to provide evidence for policy-making, to benchmark and compare the performance of a portfolio of buildings. The purpose determines the types of techniques and the scope of the evaluation: indicative, investigative and diagnostic (Guerra-Santin and Tweed, 2015). The purpose of the BPE also sets the level of detail of the study and the granularity of the data collected (Leaman et al, 2010; Roberts, 2001; Bordass and Leaman, 2005a; Bordass and Leaman, 2005b).

Whyte and Gann (2001) suggest that POE provides information about the quality and value of design to inform building developers, designers, owners and users and has the potential to increase the building industry's knowledge about usability and adaptive opportunities (Bordass et al., 2001) and to justify design strategies in buildings (Carmona Andreu and Oreszczyn, 2004).

In the UK, the BUS occupant survey evaluation[3] is a widely used methodology to investigate the occupant's perspective of buildings in use. It takes the form of a questionnaire used in the BPE to

[3] This paper focuses on the UK. Other surveys used worldwide that aim to investigate the human factors in relation to thermal comfort and energy performance; e.g. the Centre for the Built

investigate the technical performance in relation to occupants' perspectives. BUS can be used on domestic buildings, non-domestic buildings and transient spaces. The purpose is to provide a standardised tool for benchmarking and comparing buildings' physical (measured) performance and occupant satisfaction. The standardised methodology is useful for comparing and benchmarking purposes. It enables the collection of data about the occupants' views and their satisfaction regarding how the building meets their physical, psychological and health needs. The participants rate the overall comfort in the building in summer and winter, their perceptions and satisfaction with the design, aspects of environmental control and overall performance. However, there are limitations in the application of the BUS method when investigating the nexus between technical performance and occupants' factors (understood as 'behaviours, needs and desires'):

- The use of generic questions across non-domestic building types. The non-domestic building sector is diverse in terms of use, function, spatial requirements and users' needs. BUS is suited to working spaces; generic questions however aim to enable a general comparison between similar buildings.

- The use of standardised questions to identify occupants' factors does not consider in detail the complexities of occupying buildings, the different ways people interact with buildings and systems, the degree of control and the expectations in different areas within a single building and the differences between geographical and cultural contexts of application ie. cultural and social context that shape the users' expectations and behaviours. It is argued that the standardised questionnaire is a starting point for information and data collection and BUS can be tailored to suit the specific circumstances of the BPE exercise.

- The 'snapshot' application of a questionnaire to rate the occupant satisfaction and comfort could be problematic in assessing thermal experience in buildings. BUS includes questions that refer to the satisfaction in summer and winter. If administered once, the response will rely on the memory of the respondents. There are limitations in using questions whose responses are based on retrospective accounts and memory as suggested by Emmitt (2001, p.400) in a study about designers. The

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Environment Occupant Indoor Environmental Quality Survey (see https://www.cbe.berkeley.edu/research/survey.htm).

adaptive thermal comfort theory highlights that tolerance and acceptability of conditions are related to the degree of control and adaptation opportunities available to users (Brager and De Dear, 2008). There is a broader range of acceptance in the variations of temperature in buildings using natural ventilation and mixed-mode ventilation than in mechanically ventilated buildings (Brager and Baker, 2009). The seasonal variations (including conditions in autumn and spring), the temporal variations (morning and afternoon), and spatial variations within buildings are likely to affect the perception of thermal experience (tolerance and expectations). To investigate thermal satisfaction and inform intervention strategies to improve conditions, it may be necessary to link the satisfaction responses, the occupants' actions (i.e. adaptation opportunities) and the measurements of indoor environmental conditions. A limitation of a snapshot view of the users' satisfaction may compromise the holistic understanding of the interrelation between the technical performance outcome (i.e. energy use), the expectations about the indoor environmental conditions, the way people use buildings and their satisfaction with those buildings. The generic scope of BUS only allows for a limited analysis of the indoor environmental conditions in relation to occupants' responses. A deeper investigation is required to determine the diversity and the dynamics of the use of spaces and the perception of the indoor environment across seasons, between different areas or spaces in buildings, and between different user types, in relation to cultural expectations.

Soft Landings is a recent addition to the suite of BPE tools and guidance. It is a comprehensive process that recommends good practice to achieve the building targets from inception to operation (Way and Bordass, 2005). It aims to engage the different team members and building stakeholders, including designers, contractors, clients, facilities managers and users throughout the building lifecycle process. Soft Landings encourages the involvement of designers and contractors during operation to support the handover and the operation of the building (BSRIA, 2015a). It has been adopted by the UK government to enhance the procurement processes with the purpose of improve the building quality (BSRIA, 2015b).

Existing BPE methods do not seek to understand how people experience buildings apart from basic treatments of comfort. They are good at assessing how well a building meets the general needs of its inhabitants, but less useful in explaining occupant behaviour. When referring to procurement processes, Bordass et al. (2001, p. 151) argue that "focusing on the building as a physical object ignores the purpose of the building, namely social, cultural, economic and environmental benefits [...] improve health, safety and comfort; and also raise the spirits." Treating buildings as physical assets intended only to meet technical performance focuses only on one side of the picture of what buildings do. Existing methods are good at answering "what" and "how many" questions, but not so good at "why" questions. The qualitative understanding developed by some approaches in the humanities appears to offer the potential for addressing the latter by illuminating how people experience buildings and what the buildings mean to people.

Experiential approaches to building performance

The enduring definition of good performance in architectural discourse is captured in the three characteristics originally proposed by Vitruvius in his *De architectura* (first century BCE):

- *utilitas* (referring to user - fit for the purpose); and
- *firmitas* (referring to stability - performance);
- *venustas* (referring to beauty and delight). Vitruvius' concept includes factors that technically-oriented performance definitions do not embed.

Vitruvius' concept includes factors that technically oriented performance definitions do not embed. Or in Sir Henry Wotton's rephrasing: commodity, firmness and delight. In spite of their distant origins, these three conditions of 'well building' are still invoked when the quality of architecture – and how it 'performs' – is discussed.

The concerns of architectural criticism seem far removed from the BPE. It is rare to find an approach that gives equal weight to the technical performance of buildings (energy and comfort), and the satisfaction of inhabitants and their aesthetic experience of the architecture. There is a healthy environmental tradition in architecture that combines in varying degrees architectural science and architectural theory. Writers such as Banham (1969), Heschong (1980), and Hawkes (2007) underline the importance of environmental conditions to producing great architecture, but their work stands apart from the predominantly technical studies of the BPE. Instead they emphasise the symbolic and aesthetic aspects of environmental design using historical (often vernacular) or celebrated contemporary buildings to illustrate their points. Apart from Heschong, the focus tends to be more on environmental properties other than thermal. In most cases, environmental 'delight' is found in rare examples of much lauded buildings set apart from everyday experience of offices, shops and social housing. This suggests that deliberate design of the thermal environment to engender delight is exotic rather than something that might be part of quotidian design. A fundamental argument advanced here is that by extending the scope of building performance to include sensorial and experiential concerns can help us to understand why inhabitants give low satisfaction ratings with environments and the actions they take to address their concerns. The remainder of the paper will focus on one aspect of BPE – the thermal environment – to suggest how existing methods of assessing thermal performance might benefit from phenomenologically based approaches to understanding people's perceptions of the experiences that buildings offer them.

From thermal comfort to thermal experience

The history of thermal comfort studies in buildings is well documented elsewhere (de Dear et al, 2013; Brager and de Dear, 2008) and it shows a gradual widening (and arguably at least one bifurcation) of the range of approaches to describing thermal environments and inhabitants' responses to them. It parallels the course of other fields of enquiry, e.g. medicine, in which it is recognised that a physical sciences approach alone do not tell the full story and that descriptions based on analytical and empirical studies need to be supplemented by insights gathered through other means.

To summarize, the main inflection points in thermal comfort studies have been:

- development of a physiological basis to human responses to different thermal environmental conditions (Fanger, 1970).

- comparison between predicted and actual reports from occupants' about their perception of real thermal environments (Beizaee, 2012).

- recognition of human agency in responding to thermal conditions using available adaptive opportunities (Nicol, 2011; Brager and de Dear, 1998).

- recognition of the influence of cultural context on perception of thermal comfort (Heschong, 1980; Cole, Robinson et al., 2008; Brager and De Dear, 2008).

- social practices approach to thermal comfort (Shove, 2003; Chappells and Shove, 2005).

Field studies, particularly in people's homes, have shown that they often choose to create thermal conditions that lie beyond those normally considered to be comfortable (Tweed and Dixon, 2012). In some cases, therefore, it can be argued that people seek thermal experiences rather than conventional definitions of comfort. The frequency and duration of such experiences may be slight, but because they exist at all suggests they warrant exploration. Observations of other cultural and social practices suggest that people seek extreme conditions on the beach, in the sauna, on the ski slopes, in icy cold lakes, and will expend significant effort and investment to secure these experiences.

The need to go beyond the conventional understandings of comfort finds support from Ray Cole and colleagues:

> *"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."* (Cole et al. 2008, p.324)

This comment underlines the need to question continually the received wisdom with a view to improving our understanding of people-environment relations. In the following section, the paper will consider some ways in which approaches found in the humanities might contribute to our understanding of how people experience and respond to thermal environments.

Insights from the humanities

In architecture, the humanities play an important role in explaining not just the aesthetic dimensions of encountering buildings but in suggesting how designs evoke specific feelings in people. Much of this discourse tends to reify the architecturally informed observer over the lay person. Introductory texts on architectural experience, such as Rasmussen's *Experiencing Architecture* (1962), treat architecture as objects that are perceived unproblematically but require the observer to possess the expert understanding to decode their meanings and appreciate their beauty and worth. Beyond the boundaries of architecture, however, there are more general discussions about how people interact with the world that provide useful insights into the perception of building performance. The most enduring of these is phenomenology, which remains a staple of qualitative research in the humanities. Applying phenomenology to the experience of architecture is not new (Benoit and Giraud, 2012; Shirazi, 2013; Norberg-Schulz, 1980; Norberg-Schulz, 1963), but previous studies have not focused directly on building performance. This section considers how phenomenology can enrich the understanding of human environmental experience in architecture.

Being-in-the building – phenomenology and architecture

In philosophy, phenomenology emerged as reaction to the dominant rationalism. Its rallying cry was coined by Edmund Husserl as a return to "the things themselves", emphasizing the need to bracket presuppositions and concentrate on what is immediately present. Whilst rejecting Husserl's residual Cartesianism, his pupil, Martin Heidegger, retained a focus on everyday interactions between people and their environments.

In architecture, phenomenology has been invoked and applied at different scales and specificities, from Christian Norbert-Schulz's adoption of Heidegger's ideas on sense of place (genius loci) (Norberg-Schulz, 1980) through Bachelard's treatment of intimate spaces (Bachelard, 1964) to Juhani Pallasmaa's celebration of sensorial engagement with surfaces and textures of specific materials (Pallasmaa, 1996). The departure points for most architectural excursions into phenomenology are provided by the philosophers, Martin Heidegger and Maurice Merleau-Ponty.

Phenomenology and thermal experience

Two main tenets that are agreed by many phenomenologists:

- phenomenology rejects the dominant rationalistic model of experiencing and acting in the world, the model derived from the Cartesian *Cogito* (cogito ergo sum, or I think therefore I am), in favour of an 'absorbed coping' as the primary mode of engaging with the world.

- phenomenology rejects the mind-body separation inherent in the Cartesian *Cogito* and views the 'lived body' as the primary locus for being-in-the-world. Rather than treat mind and body as different entities, they are seen as a unified whole that elevates consideration of perception and the relationship between sensory experience and cognition.

Both of these premises have important insights to offer the study of thermal environments and people.

In *Being and Time* (Heidegger, 1962) Heidegger dismantles the dominant model of how we experience the world. Contrary to the rationalism of René Descartes, he insists that most of the time we are engaged in 'embodied coping' rather than conscious, deliberate thought about our interactions with the world. In this view, individuals are embedded in situations and engaged in trying to satisfy goals that can be described at different levels of abstraction and generality, from making a living to keeping warm. Objects and aspects of environments for the most part are present as an undifferentiated whole that provides the context for our being-in-the-world. This embodied coping with the world and its contents emphasises the role of context in shaping our experiences in contrast to the disembodied, independent and universal truths of rationalism that form the basis of physiological descriptions of thermal comfort. Absorbed coping disrupted through breakdown emphasises the role of inhabitants in taking action to achieve their goals, which is recognised by Cole et al (2008):

> *"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." (Cole et al, p.324)*

Existing approaches to investigate thermal experience as a factor in building performance do not describe this active role in much detail. Phenomenology offers a framework for doing so. The phenomenological concepts of 'breakdown' and 'lived body' could shed new light to investigate in more depth the inhabitants' thermal experiences, the conditioning of the built environment and their implications in the energy performance of existing buildings.

The role of 'breakdown' in experiencing environments

Central to Heidegger's description of being-in-the-world is the idea of 'breakdown,' which results when things do not go according to plan. He argues that it is only when something disrupts the default coping mode that objects emerge from their contexts as things that are then subjected to scrutiny and reasoning. He uses the example of a carpenter engaged in hammering that is interrupted when the head flies off the hammer. Heidegger's German neologisms describe the transition of the hammer's status during breakdown, which are usually rendered in English as the cumbersome terms "ready-to-hand" — the default mode of the hammer's existence during the activity — and "present-at-hand" — the emergence of the hammer as an object for contemplation (Dreyfus, 1991). Heidegger claims we only become aware of objects in the world when something unusual happens to throw us out of automatic engagement or absorbed coping. Objects thus 'reveal' themselves to us following breakdown. In other words, until the head flies off the hammer we are simply engaged in the activity of hammering and only marginally aware of the existence of the hammer or the nail. If the hammer breaks or we hit our thumb then suddenly these objects emerge from the general background to demand conscious attention as we slip into a deliberative mode of thinking.

There is a corollary with thermal experience. For the most part we are unaware of thermal conditions. In Heidegger's terms, the thermal environment is "ready-to-hand." It only demands conscious attention, reveals itself as an environment and occasions deliberate thought and action when we are surprised by its emergence either through discomfort or delight. This may happen through the sudden realisation that we are too warm, a cold draught felt at the ankles, the unwelcome chill of a handrail or the unexpected but pleasant feeling of sunlight on the face. This is where the meaning of thermal environments emerges and is most likely to initiate action on the part of the building inhabitant. The thermal environment shifts from being ready-to-hand to being present-at-hand when it intrudes on our goal of seeking comfort or preferred thermal conditions. It is these "breakdowns" in the thermal environment that trigger inhabitants' behaviour.

The rational response of an architect, building services engineer, or facilities manager to the idea of breakdown might be to design out the possibility of their occurrence. Such an approach leads to the creation of thermal neutrality in the built environment, resulting in standardised comfort expectations that increase the energy consumption. However, this would be to miss the point entirely because according to Heidegger's account, breakdown is inevitable no matter what advance precautions are in place. It becomes more a matter of how continued coping is supported.

Phenomenology has gained traction in other areas of design, most notably in human-computer interaction studies (Winograd and Flores, 1986) and experience design (Wendt, 2015), in which it is used to inform discussions about usability. As Wendt notes, the tasks carried out to assess usability of devices and "the means by which we measure ease of use are usually quite mechanical" (Wendt, 2015, p.31), which is also true for the BPE, to the point of triggering breakdown through surveys that draw attention to environments with which inhabitants are already coping. A phenomenological approach would promote maximising the availability and effectiveness of coping mechanisms over removal of all possibility of breakdown.

The lived body in thermal experience

Phenomenology considers the lived body as the primary locus for being-in-the-world. While Heidegger is mostly quiet on this topic, it is central to the later work of Maurice Merleau-Ponty (Merleau-Ponty, 1962) and contemporary phenomenologists (Welton, 2010). Merleau-Ponty's criticism of the Cartesian view of the world is that it relegates the body to the perfunctory role of providing a home for the mind. Rationalistic thinking is riven with dualisms including between mind and body, subject and object, person and world *etc*. Phenomenology rejects these dualisms, most notably that between mind and body. For most phenomenologists it is impossible to separate one from the other because our knowledge of the world is acquired through our involvement with it through our lived bodies. This is what has led Dreyfus (Dreyfus, 1992) and others to counter the wilder claims from the artificial intelligence (AI) community based on representations of the world as collections of facts and rules that are independent of context. The world of the BPE is no different.

In the earliest thermal comfort studies the body is treated purely as a biological machine responding to different environmental conditions through physiological mechanisms such as sweating. It is devoid of any capacity to react beyond a small range of physiological processes, again such as sweating. The adaptive model of thermal comfort, allows the body to become more animated and gain the ability to think, move and take advantage of opportunities offered by the immediate environment to change how they respond to conditions—change the level of clothing, consume hot or cold drinks, etc. However, the treatment of the body is far removed from being the primary conduit for being and experience. In current standards of thermal performance, the body is absent and thermal comfort is portrayed solely as a state of mind: 'Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation' (ANSI/ASHRAE 2010). To reduce human experience and action to this level obscures the most interesting aspects of how inhabitants interact with their environments. It offers no clues about how to design better buildings and systems. The definition also raises methodological questions about how a "condition of mind" expresses satisfaction without being asked, which in itself constitutes a phenomenological breakdown throwing the subject into a deliberative mode of thinking that may skew the answers.

Merleau-Ponty's focus on the lived body and its potential for extension through tools (walking canes, even ostrich feathers in a hat) adds new layers to debates about how inhabitants experience environments and modify their behaviour (Merleau-Ponty, 1962). It ushers in a raft of interesting issues to explore that include competences (Ingold, 1992; Ingold, 2000), skills (Dreyfus, 1996) and different conceptions of the body (Foucault, 1973). The conception of the body and how that is reflected in different approaches to thermal comfort is the topic of a forthcoming paper (Tweed, 2018).

The above account suggests the humanities – and phenomenology in particular – can offer different perspectives on how building inhabitants experience and react to thermal conditions. It highlights ways to explore the uncharted waters of the meaning of thermal environments as a neglected aspect of determining the performance of buildings. Phenomenology also offers opportunities to extend the analysis beyond individual experience to include social dimensions (Schutz, 1962). In a previous paper, Tweed (2000) has suggested how Anthony Steinbock's reworking of late Husserlian phenomenology can provide a framework for describing architectural experience to account for variations resulting from individual differences, life stage, and cultural context (Steinbock, 1995).

Evidence from the field

None of the field studies mentioned here set out to apply phenomenological approaches. However, retrospective scrutiny of the findings suggest that phenomenology may offer explanatory power over conventional methods of investigating thermal comfort in practice and could have revealed more about the relations between inhabitants and their environments. Despite the lack of an explicit phenomenological approach, there are clues among the authors' projects that suggest a more detailed understanding could be developed in later studies. Three projects are discussed below and in all cases, they demonstrate the benefits of conducting research on thermal experience using methods that elicit the response of individuals immersed in actual environments at the time they are experiencing them. The findings challenge performance-based standards and methods for determining inhabitant satisfaction, revealing a more complex picture of how people use their dwellings. In the past decade, architectural research has adopted ethnography and associated methods across (Lucas, 2016). Indeed the development of thermal comfort studies mirrors the progression of studies in other areas which have moved from a narrow physical science approach to a more inclusive and exploratory investigation of everyday human behaviour linked to the measured performance data, which began with the development of theories of adaptive comfort that include human action (Baker, 1995; de Dear and Brager, 1998; Nicol, 2011), and has continued, for example, through renewed interest in the concept of alliesthesia — a hypothesis that suggests non-steady-state environments can create conscious experiences of thermal pleasure (de Dear, 2011).

The discussion here revolves around three main research projects that have fed the development of the current approaches being applied in the Welsh School of Architecture:

1. Carbon, Control and Comfort (CCC): user-centred control systems for comfort, carbon saving and energy management, a multi-university collaboration funded by the Engineering and Physical Sciences Research Council (EPSRC) and E.On.

2. Conditioning Demand (CD): Older People, Diversity and Thermal Experience, a multi-university project funded by the EPSRC and Électricité de France (EDF).

3. Solutions for a Holistic Optimal Retrofit (SHOR), a "Retrofit for the Future" project funded by the Technology Strategy Board.

The role of the Welsh School of Architecture in these projects varies from primarily conducting the physical measurements (CCC), carrying out detailed interviews and spot physical measurements with householders (CD) to the full gamut of design, installation and monitoring — both physical and social — in the retrofit project.

The aim of the CCC project was to discover what kinds of thermal environments people created and maintained in their own homes. The hypothesis was that domestic thermal environments would differ significantly from those that might be predicted by existing thermal comfort theory. The research team sought to reveal how people operated their homes and why they did so in that way. The project monitored nine dwellings in South Wales and 10 in Harrogate. The WSA team was in charge of the monitoring in S Wales and worked with colleagues from Leeds University on developing appropriate protocols and methods for all of the monitoring on the project. The WSA team also worked closely with colleagues from Kings College on the collection of social data through interviews and A/V tours of the dwellings. The results were published by Tweed, Dixon, Hinton and Bickerstaff (2014).

One of the most interesting issues in the CCC project was methodological: what is the best way to determine people's perception and satisfaction with the thermal conditions in their homes? Many studies conduct questionnaire surveys in buildings and collect data often asking for retrospective reports from inhabitants about how comfortable they were at some earlier time—sometimes several months or a season distant. In this project, the team wanted to ensure that the survey data could be related to continuous physical measurements of temperature, relative humidity etc. The resulting methodology used a telephone survey during which each household was contacted three times per day for five consecutive days including at least one weekend day. The development of this research design was informed by a phenomenological understanding of the importance of capturing how inhabitants' interact with their immediate conditions and the method of experience sampling (Csikszentmihalyi and Rochberg-Halton, 1981). This represented a deliberate intervention to invoke a 'breakdown' that brought current perceptions to the fore instead of potentially unreliable historical accounts. The use of this methodology revealed inhabitants' concurrent perceptions of environmental conditions.

The CD project followed a different line of enquiry and focused almost entirely on the reported experience of older (55+) householders following energy retrofits to their homes in the form of fabric upgrades (insulation and draught-proofing) and system changes (low carbon fuels). The WSA team conducted fieldwork in 11 dwellings in South Wales alongside colleagues from the University of Exeter, who studied a similar number properties in Devon and Cornwall, and other project partners in Manchester and Lancaster who investigated different types of residential properties – a care home and an assisted living development – associated with older people. Unlike the CCC project, the properties studied in this project were privately owned and occupied rather than the social housing studied in CCC.

The WSA role in the CD project was to carry out interviews with the householders in winter, spring and summer. The semi-structured interviews included the following topics: changing attitudes to and perceptions of the thermal environment with age; adaptive comfort tactics; use of dwelling; use of the heating system and its controls; attitudes to energy consumption; importance of costs. The transcripts reveal a deep engagement between inhabitants and the fabric and systems in their homes. The level of interaction and the skill demonstrated by some inhabitants in achieving their desired thermal experiences was a surprise. It begs more detailed phenomenological studies that could help to explain key behaviours. For example, many of the respondents showed a well developed sensitivity to external conditions and modified their behaviour, including the use of the heating system, based on their own weather forecasts. There are opportunities to exploit this interest in low energy design, if we had a better understanding.

The CD project underlined the need to consider building performance as a whole rather than treating them as discrete aspects. Householders discussed their home conditions in the context of what they enabled them to do or prevented them from doing, and not as isolated sensory experience, though these were mentioned too, e.g. when draughts caused particular discomfort.

The SHOR project was a retrofit of an end-of-terrace two-storey property owned by a housing association in south Wales. As noted above, the WSA carried out the design of the retrofit, oversaw the installation of the monitoring equipment and collected the data from this, and conducted a series of interviews with the tenants to establish their response to the retrofit and any changes to their behaviour following its construction. Though the retrofit was primarily to reduce the CO_2 emissions from the dwelling by at least 80% (the goal of the Retrofit for the Future programme), in practice the housing associations made use of the initiative to improve other facilities in the property: a new shower and increased storage for personal effects.

In the SHOR project, the need for a nuanced and richer method of understanding how people interact with their homes is highlighted by the householders' sensitivity to qualities of the environment that would not be picked up by traditional methods. For example, much of their behaviour, which had a direct effect on the thermal environment, can be explained by their perception of the family dog's needs. The intentions behind a sunspace, designed to provide a thermal buffer between the exterior and the living room, were undermined by the family leaving the door between this space and the living room open so that the dog could have free passage between the two, thereby negating the thermal energy benefit of the separation (Tweed, 2013).

Housing as a special case for investigating performance

Housing presents very different problems for creating thermal environments and in assessing their performance compared with other types of buildings. Dwellings may need to cater for more diverse thermal requirements. The range of activities in the home is wider than will be found in most other types of buildings resulting in wider variations in clothing levels, metabolic rates. There is often greater diversity in the needs of people sharing a home environment in terms of their ages, levels of activity and occupancy patterns. There is the crucial difference in the agency of the building inhabitants in the residential sector. Unlike the housing sector, in many non-domestic buildings the inhabitants have little or no control over their immediate environment. In extreme cases, control of the heating system is not even available within the building but is centralised at another location possibly even offsite.

The studies described above underline the importance of considering context when studying how people use and respond to environmental conditions. Perhaps the most interesting observation from these studies is that the pursuit of desired thermal experience appears to override other concerns, including the cost of providing that experience. The immediate satisfaction of thermal preferences seems, in some circumstances, to take precedence over the longer term issues of paying for them.

The key points to emerge were:

1. Some people are adept at operating their homes in a way that secures the environment they want from them and show a sound understanding of environmental principles, including not just climatic conditions but the operation of heating systems. Phenomenological concepts (absorbed coping, lived body) could deepen our understanding of the relationships between people and their thermal environment and the implications to energy use.

2. The pursuit of thermal experiences in homes tends to deviate from traditional definitions embedded in thermal comfort theories and performance definitions. Phenomenological concepts of breakdown and the lifeworld emphasise the absorbed, holistic nature of most human experience and opens new avenues for more detailed investigation to inform future design for better performance.

3. Thermal environments at home are diverse (differences across seasons, across spaces). There is a dynamic landscape of thermal experiences at home: (who is the receptor/who engages/ whose thermal experience is to be satisfied; spatial and temporal variations). Phenomenological concepts of engagement through the lived body remind us of the transient, dynamic and evolving features of thermal environments.

With the benefit of hindsight from revisiting the results from these projects, we see opportunities for enriching the study of human-environment relations and how these influence the evaluation of building performance. The major contribution phenomenological methods could have made to these previous studies lies in the development of methodologies that recognise ‘absorbed coping’ as the dominant mode of being in the world and how this impinges on perception of buildings and their systems, which in turn shapes behaviour. There are also clear signs that approaching human-environment investigations from the ‘lived body’ perspective may offer increased explanatory power beyond the conventional treatment of humans as thinking metabolisms. In our observations of how people respond to particular environments, there is evidence that initiating the actions needed to make a change to the thermal environment is not just a rational decision-making function but is in part influenced by the physical bodily effort required to make that change, such as: going to the place where a sweater is stored and then putting it on; getting out of a chair and making a change to switch, thermostat or timing control to control heat generation and emission in a home. The definition of ‘effort’ in human behaviour that impacts on environment and energy in buildings needs to transcend a simple definition that treats mind and body separately.

Lessons from the humanities

This paper has explored the contribution that phenomenology can make to understanding people’s everyday experience of thermal conditions in buildings. There are three further key points to make. First, the focus on the thermal environment aims to reduce the complexity of addressing building performance *in toto*, but there is ample evidence to suggest that similar approaches can be applied to other dimensions of experience. For example, Don Ihde, a contemporary phenomenologist and philosopher of technology, has developed a comprehensive phenomenological treatment of sound (Ihde, 1976) and Edward Casey has developed broader treatments of the experience of places (Casey, 1998). The second point is that phenomenology is just one approach within the humanities and social sciences that may be brought to bear on the problems of describing everyday experience. However, it is widely acknowledged as established approach to studying experience of the world from multiple perspectives and shares much of its conceptual structure with, for example, American neo-pragmatism (Hickman, 2001). Thirdly, we should not assume that phenomenology is a unified field. Like most schools of thought, there is significant disagreement within it and trenchant criticisms aimed at it from outside. However, it is well established as a recognised approach to studying real world phenomena (Moustakas, 1994; van Manen, 2014).

The key contribution of humanities based approaches is that they may bring to the fore neglected aspects of performance that would otherwise be overlooked. Whilst existing tools for evaluation are good at determining the broad outlines of how a building will meet the needs of those who use it, they are not able to tell us why inhabitants like or dislike it. That tends to be addressed through the conventional physiological explanations of the past. Even adaptive comfort theory does not consider in depth *why* people put on jumpers or drink cool drinks, merely that they do so to ameliorate conditions they do not like.

If we understand why people behave as they do in response to thermal conditions using a phenomenological, user-centred approach perhaps we could anticipate those actions at the design stage and rather than aim to meet abstract target temperatures. We could provide buildings that provide range of opportunities for responding to the environment and providing the experience individuals in the buildings seek. That is what design should be doing. It is not about providing a fixed building that ignores what eventual occupants might want, but about providing buildings that offer a range of mechanisms under the control of the occupants to adjust and exploit as they see fit. It is about considering buildings as 'events' not as 'static objects': 'fixity and permanence are strictly human conceits; built environments are material and social events in a continuous state of becoming' (Friedman 2015, p. 267). This is the essence of the "long life, loose fit, low energy" dictum of Alex Gordon (Langston, 2014).

Wendt (2015), in his discussion of experience design, claims that the deliberative actions people take to bridge the gap between non-preferable and preferable states is design. Applying this to the thermal environment suggests buildings and systems need to offer the tools through which inhabitants can achieve preferable conditions.

Conclusions

This paper has sought to introduce ideas drawn from the humanities, primarily phenomenology, to enrich current approaches to the BPE with the aim of understanding why buildings inhabitants behave as they do in response to thermal environmental conditions. The paper has been inspired in large measure by the work of Cole (Cole et al., 2008) and others who have sought to enlarge the remit of thermal comfort studies beyond the physiological and psychological to embrace cultural context. The paper has argued for a further extension that includes studies of the deeper connections between people and their enveloping lifeworld. It is not a plea to add more variables to evaluation tools and methods, but for heightened sensitivity to the wide range of thermal experiences inhabitants may seek and the actions they may take to achieve those with the recognition that this involves the whole person, who is engaged unconsciously in fully absorbed, skilful coping with a world that has, but is not solely defined by, its thermal state. It is a call for the investigation of the *meaning* of thermal environments to different people in different contexts at different times. By understanding the meaning of thermal environments, designers will be better equipped to provide buildings and systems that will allow inhabitants cope with the unavoidable 'breakdowns' that emerge between non-preferred and preferred environmental conditions. This area warrants further investigation; for example, comparing designers' intentions to inhabitants' use of buildings and analysing how designers incorporate knowledge of inhabitants' experience to inform the design of future buildings.

The trajectory of thermal comfort studies is analogous to that of other areas of inquiry such as in medicine. Just as health and well-being are seen as more than the absence of illness, in which people are seen primarily as biological mechanisms and illness as a physical problem to be fixed using established medical solutions such as surgery or medication, so the health and well-being of buildings are now revealed to be more complicated than before. The edict of 'treating the whole patient' applies as much to buildings as it does to individuals.

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