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The Science of Comfort: Constructing Normality

There is no doubting the rate and pace of *indoor* environmental change: over the last hundred years or so, conditions inside have changed significantly. Traditional methods of managing climatic variation, such as the siesta, are in decline. Meanwhile, people in cold climates have become used to wearing lightweight clothing all year round. Increasing dependence on resource-intensive heating and cooling technologies continues to drive energy demand and associated emissions of CO_2 and in this there is an ironic but problematic link between the dynamics of indoor climate change (especially cooling and the diffusion of air-conditioning) and those of global warming. Expectations of the indoor environment are evolving and apparently converging around the globe and around a concept of comfort that is immensely demanding to maintain and reproduce. The amount of energy and of artificial cooling required to sustain recognized standards of comfort in the fastest growing cities in the world is truly frightening. Partly because of this, there is increasing recognition that new, more environmentally forgiving specifications may be required. This is tricky because although notions of comfort have changed historically and between societies, engineers and designers are unlikely to flout established technical standards or challenge conditions of comfort that people have come to expect.

This chapter considers the making of comfort as a concept and as a material reality. It looks at how comfort has been defined and how commercial and scientific interests have together led to the specification of standards with which we are now familiar. As represented here, the story is quite straightforward. I argue that despite and partly because of the seemingly innocent goal of meeting peoples' needs, technical research (allied to commercial interest) has contributed to the convergence of indoor environmental conditions and the naturalization of ultimately unsustainable expectations and arrangements. In figuring out why meanings of comfort take the form they do today, I pay particular attention to the assumptions and priorities that have structured the scientific specification of human need. Whose knowledge and interests are embedded along the way and what difference has this made to the sizing and specification of heating and cooling technologies and the design of the built environment? This is not an especially novel line of questioning. Many other studies have taken a similar route, demonstrating how institutional and political factors shape the production of knowledge, the resolution of controversy and the course of technological innovation (MacKenzie 1990).

Taking a similar approach, but taking it a stage further, this chapter goes on to investigate the translation of science into (design) practice and the relation between design and social convention. Standards play a critical role in this mediation. International codes like those developed by the American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE) prove to be immensely influential, acting as a common point of reference and as a co-ordinating mechanism powerful enough to align engineering and manufacturing practices around the world (Schmidt and Werle 1998). Also relevant for this discussion, the standards-making process has been built upon a distinctive yet contested genre of scientific enquiry. Representations of comfort as a standardized set of conditions conflict with those informed by 'field studies' demonstrating cultural variation in meaning, experience and expectation. Current controversy over the technical specification of thermal comfort is sociologically interesting on two counts. As well as illustrating the fluidity of a concept that is presented as 'natural' and unchanging, it highlights the close relationship between science, standards, markets and representations of consumer need. It is of further environmental relevance in that a more flexible approach to the definition of comfort promises to justify and legitimize less energy-intensive design solutions and stem the undoubtedly damaging convergence of convention and practice.

In reviewing the history of thermal comfort research and the standardization of the indoor climate this chapter tells a tale of escalating demand grounded in naturalizing and universalizing concepts of human need and sustained by equally global forms of commercial interest and professional expertise. In terms of the architecture and argument of the book as a whole, the chapter's primary purpose is to illustrate the social construction of energy consumption and to describe the historical development of conditions and conventions that are now taken for granted. It starts with the very idea of comfort, showing how its meaning has evolved. This puts contemporary definitions of comfort into context. The chapter goes on to show how human comfort has been specified and to detail the kind of research involved. As I explain, universalizing programmes of physiological enquiry have informed engineering standards that have, in turn, shaped the design of the built environment and the comfort-related expectations and experiences of those who inhabit it. In taking this course the chapter shows the malleability of the concept and how it has been reified and fixed in place. While biological definitions dominate, there are other equally 'scientific' ways of specifying what people need. Widespread adoption of the alternative so-called adaptive approach would involve reconceptualizing comfort (defining it as an achievement rather than an attribute) and would lead to the construction of a different sort of indoor environment. In considering this possibility, I conclude by reflecting on the extent to which scientific and commercial interests literally construct normality – building conditions and conventions at one and the same time.

The chapter concentrates on the design and management of the indoor climate, but begins with a more general review of comfort variously defined as a state of mind, an attribute and an achievement.

Defining Comfort: a State of Mind, an Attribute or an Achievement?

If you are sitting comfortably then I'll begin. These words, familiar to those who enjoyed the children's radio programme 'Listen with Mother', provide as good a starting point as any. Used to introduce the short story featured in each lunchtime episode, this phrase conjures up an image of cosy anticipation: it suggests a state of mind as well as a proper disposition of the body.

'Comfort', from the Latin verb 'confortare', was first 'adopted in Middle English with the meaning of mental or physical strength, encouragement or consolation' (Heijs 1994: 43). Such interpretations live on when giving someone a comforting hug or when writing words of comfort in times of trouble. A bibliographic search on the keyword 'comfort' consequently reveals innumerable references to religious books and pamphlets, many of them dealing with bereavement. Examples include, *To Begin Again: The Journey Toward Comfort, Strength, and Faith in Difficult Times* (Levy 1999), *The Needs of the Dying: A Guide for Bringing Hope, Comfort, and Love to Life's Final Chapter* (Kessler 2000), to pick just a few. These expressions of comfort have to do with sharing and support but there are other more individualistic formulations, as when someone claims to be comfortable with a decision or when they look forward to a comfortable retirement (Salisbury and Robinson 2001). Although comfort is generally a good thing, comfortable complacency is a danger to be guarded against, especially in business. A number of management texts offer advice and guidance on how to spot and eradicate this problem. O'Toole's (1995) book on *Leading Change: Overcoming the Ideology of Comfort and the Tyranny of Custom* positions comfort as a threat to business success as does Bardwick's volume of the same year, *Danger in the Comfort Zone: From Boardroom to Mailroom-How to Break the Entitlement Habit That's Killing*

American Business (Bardwick 1995). Although interpretations of comfort as a state of mind persist, other much more material definitions dominate.

In following the terminology of comfort from its initially spiritual meaning through to its modern incarnation as 'self-conscious satisfaction with the relationship between one's body and its immediate physical environment' (Crowley 2001: 142) the historian John Crowley notices that the explicit valuing of *physical* comfort represented an important shift of emphasis. With this shift, the terminology of comfort was applied to the means by which that state might be achieved as well as to the state itself. As Heijs explains, from being a subject-bound concept having to do with relations between people, comfort, 'developed into a more object bound term, also denoting worldly goods which could enhance mental and physical well-being.' (Heijs 1994: 43). Redefined in this way, comfort had to do with things, conditions and circumstances.

The pursuit of comfort consequently inspired practical programmes of action and enquiry. Writing of the eighteenth century, Crowley observes that political economists, moral philosophers, scientists, humanitarian reformers, and novelists 'sought to evaluate the relations of body, material culture, and environment in the name of physical comfort'. He continues 'They gave the term "comfort" a new physical emphasis as they reconceptualized values, redesigned material environments and urged the relearning of behaviours' (Crowley 1999: 750). Crowley claims that this led to a further naturalizing of the concept and of the conditions associated with it. In explaining that the achievement of comfort legitimized new forms of consumption, Crowley notes that the term was 'increasingly applied to a middle ground between necessity and luxury' (Crowley 1991: 758). As such it provided a useful benchmark for social reform, offering a point of reference against which to assess 'normal' societal entitlements. This implicitly *universalized* understanding of need allowed philanthropic reformers to assert 'a common humanity on the basis of physical comfort' (Crowley 1999: 772). Soon enough, the goal of providing and achieving conditions of comfort required no further explanation. Illustrating this way of thinking, the UK's Chartered Institution of Building Services Engineers (CIBSE) marked its hundredth anniversary with a short volume entitled the *Quest for Comfort* (Roberts 1997). As well as justifying a century of engineering, the title suggests that comfort exists independent of the means and technologies by which it is produced and known.

This is not necessarily the case. Although entitlements to comfort are taken for granted, it is not always clear quite what that involves. When comfort is materialized and defined as an attribute, for example of clothing or furniture, it makes sense for designers and manufacturers to develop and deliberately enhance this feature, selling comfort as an aspect of what they produce. But what is this quality and who defines it?

Writing about the history of the chair, Giedion (1948) concludes that definitions of comfort reflect the relative influence of upholsterers, engineers and scientists. He illustrates this point with reference to French furniture of the 1850s. Upholsterers were, he claims, especially influential in constructing concepts of comfort embodied in a singularly 'boneless' type of chair known as the 'confortable'. Initially unusual in being totally covered in fabric and tassels and in having huge arms but no visible legs, squashy arrangements of this kind dominate the furniture showrooms of today. The fact that conventionally comfortable chairs and sofas rarely provide support of the kind that the human body 'requires' points to a rift between concepts of comfort as represented in the popular aesthetics of furnishing and those based upon the systematic study of backs and bones.

Anatomical and ergonomic analyses of posture and position, twinned with medical research into the causes and characteristics of back pain, has resulted in a wealth of data relevant for the specification of 'comfortable' seating (Cranz 1998). The trouble is that what ergonomic researchers recommend does not translate into chairs that people find comfortable, leading Cranz to reach the ergonomically unhappy conclusion that 'People seem to respond more to their *ideas* about comfort than to their actual physical experience of it' (Cranz 1998: 113). Anxieties about public health, child development and productivity have, however, prompted the development of European design standards and, in this context, science is the undisputed arbiter of need.

Giedion's work raises one other issue important for the specification of comfort. His discussion of the design and function of moveable medieval chests and stools, the specialization of dressers, desks and shaving tables, and the evolution of rocking and reclining chairs is at the same time an account of the societies in which such devices made sense. In other words his history of furniture is also a history of eating, storing and sleeping and of how these practices relate to concepts of well being, propriety and comfort. In a subtle but critical switch of perspective it is possible, and perhaps sensible, to view chairs, dressers, tables, and so forth, not as embodying comfort but as the tools with which this state is *achieved*. It is obviously difficult to specify the relation between objects and the meanings and experiences they make possible. Yet it is clear that the process of being and making oneself comfortable stretches beyond the appropriation and use of individual commodities, even when those objects are imbued with attributes of comfort.

In commenting on the changing meanings of comfort, I have highlighted a number of key developments, starting with the eighteenth-century redefinition of comfort as a physical condition and as something that people have a right to expect. Examples from the history of furnishing show the specification of comfort to be a contested topic. They also show the relevance of scientific enquiry as a means of determining human need and establishing universally applicable standards. The representation of comfort as an attribute, rather than as an achievement, has also dominated the history of thermal comfort research and the design of the built environment. One consequence is that what were 'wide, and in large part discretionary, social variations in consumption patterns regarding heating and lighting' (Crowley 2001: x), have converged around a remarkably narrow specification of normal and appropriate conditions indoors. In the next sections I look at how this has come about and how is it that so many people spend their days in an environment that wavers little around 22 °C and that stays the same all year round, whatever the weather outside.

Playing God with the Indoor Climate

Bellows, spits, trivets, tripods, firedogs and ingle-nooks went through successive rounds of development but it was not until the eighteenth century that heating and cooking attracted sustained scientific and technical interest. Crowley suggests that 'as the value of physical comfort became more explicit and desirable, the technology of its improvement gained intellectual prestige' (Crowley 2001: 171). For this and other reasons there seems to have been an explosion of enthusiasm for redesigning all manner of things about the house. Even the most humble arrangements came in for serious and increasingly systematic study. Driven by a commitment to improving the basic technologies of the home, key figures like Benjamin Franklin and Benjamin Thompson, better known as Count Rumford, turned their attention to the physics of thermal efficiency and the basic principles of the open fire and the stove. Much preoccupied with the causes and cures of smoky chimneys, theirs was a measured and explicitly scientific approach.

Count Rumford's views on method underline his reliance on rigorous experimentation. He writes as follows: 'In attempts to improve, it is always desirable to know exactly what progress has been made – to be able to measure the distance we have laid behind us in our advances' (Roberts 1997: ii). The results of Rumford's experimental work resulted in designs that undoubtedly enhanced conditions for many. The 'Rumford' fireplace, which had spayed sides to throw heat back into the room and a narrow throat to optimize the chimney's draw, increased efficiency so dramatically that some reportedly found it 'too hot' (Wright 1964: 114). The application of experimental method generated new understanding of the processes of convection and radiation and in turn inspired what Heschong describes as a 'flurry of effort to design the perfect furnace' (Heschong 1979: 14).

Despite being hailed as the 'apostle of comfort' (Wright 1964: 113), Count Rumford and other gentlemen scientists of his time were not concerned to detail the optimal conditions and characteristics of the indoor environment. Their more immediate goal was to enhance the performance and output of heating and cooking devices. Such endeavours were guided by a theory of progress and improvement and by ambitions of reducing smoke, increasing efficiency and lowering cost. But at this point the definition of comfort was not itself an issue. The science of comfort, that is the scientific study of comfort conditions, came later and came as a consequence of the capacity to 'play god' with the indoor climate. Partly inspired by the likes of Franklin and Rumford, the development of heating and cooling technologies went hand in hand with new methods of measurement and control and by the 1920s it was possible to chill, warm, humidify, ventilate and modify the indoor climate reliably and with some precision. It was at this point that it became necessary to ask and to answer the question: 'what should the indoor environment be like'?

At the time when this issue first arose, climatological theories about the relation between civilization, progress, performance and human behaviour were the subject of much debate. Huntington's *Civilization and Climate*, published in 1915, was, for instance, concerned to explain why 'people of European races are able to accomplish the most work and have the best health' (Huntington 1924: 6). Given the ideological, political, not to mention racial significance of these ideas, the prospect of air-conditioning was of immense importance: here was a 'tool that would allow all humanity to progress beyond the accidents of climate' (Ackerman 2002: 41). Who knew what social and geographical consequences might follow the artificial cooling of the tropics and the consequent unleashing of mental and physical productivity until then believed to be sapped and stifled by the natural climate?

Although no longer viewed in quite these terms, the capacity to manipulate indoor climates at will generates a number of still disquieting questions about the relation between nature and civilization. Manufactured weather is a key ingredient in utopian visions of the future. A Stram Steel brochure that makes the point explicitly 'Modernism means air-conditioning . . . How refreshing to step into your home and know in advance that the temperature and humidity will be just right' (Ackerman 2002: 87). But at what price do we cut ourselves off from nature? It is one thing to modify the elements but when buildings are constructed as climatic fortresses, the symbolic division between a managed interior and an unruly and unpredictable world outside is ever more strongly pronounced.

Whether at home, in the car, or at work people inhabit a protected bubble of artificial climate, the conditions and characteristics of which have been determined by scientific research. One doesn't have to reach far into the sociological literature to come upon the idea that science, far from being the solution, is at the root of many of society's ills (Beck 1992). Sure enough, the very uniformity of the indoor environment is itself a cause for concern: is it right to keep 'human' animals indoors all the time? What has been lost (the sensation of thermal variation, fresh air, a connection with the natural rhythms of the day and the year, and so forth) and gained (increasing incidence of asthma, sick building syndrome . . .) by constructing the man-made environments in which we spend so much of our day? This kind of lingering unease is given dramatic expression in Philip Kerr's (1995) novel, *Gridiron*. This is a story of a high-tech building, the sophisticated controls of which are taken over by the software of a child's computer game. Consistent with conventions of the game, and the genre, the building turns its considerable armoury of indoor climate controls back upon its unfortunate inhabitants, destroying them one by one. The moral is clear: don't play god with the weather.

This warning acquires other more sinister overtones when we recall the global environmental costs of maintaining what we now think of as comfortable conditions inside. In a prophetic statement, Huntington, author of *Civilization and Climate*, observes that 'each advance in our so-callled control of nature makes us more dependent than before upon the continued existence not only of the artificial conditions which we create, but upon the natural conditions which alone make it possible to create the artificial conditions' (Ackerman 2002: 144). On reflection, it is extremely strange that so much energy and effort should be invested in controlling nature in order to construct conditions that suit the supposedly natural needs of the human body.

The next sections consider the history and the role of thermal comfort research in an attempt to explain how this situation has come about. Initially established in industry laboratories in the 1920s, thermal comfort research was designed to determine and define what conditions should be like indoors. Now undertaken in universities and specialist research groups, the study of thermal comfort involves a range of disciplines including building physics, ergonomics and modelling. It is a complicated field in which debates are full of technical detail. Cutting through many of the subtleties, I show how the idea of comfort as an attribute has been operationalized and specified through successive programmes of mostly physiological enquiry.

Quantifying Comfort

Compared with cold blooded creatures, human beings are soft, thin skinned and vulnerable: things soon go wrong if they get too hot, cold, wet or dry. People none the less live in an immense variety of climatic conditions including the tropical, the arctic and the arid. Protected by shelters ranging from the thin fabric of a tent to the thick ice blocks of an igloo, they have found ways of modifying the thermal variability of the outdoor environment. As Humphreys observes, the management of comfort 'pre-dates by thousands of years the development of the theory of heat exchange' (Humphreys 1995: 5). But because building scientists, architects, designers, engineers and technical experts have come to take an essentially physiological view of human comfort so much for granted, this reminder comes as something of a shock.

The 'heat balance model' to which Humphreys refers describes the physical relationship between a person and his or her environment, comfortable 'neutrality' being that state in which the heat generated by the human body is equal to the heat transferred away. It is worth highlighting two features of this foundational model. First, and as Brager and de Dear explain 'Heat balance models view the person as a passive recipient of thermal stimuli and are premised on the assumption that the effects of a given thermal environment are mediated exclusively by the physics of heat and mass exchanges between body and environment' (Brager and de Dear 1998: 84). Second, and related to this, the model predicts that people will report being comfortable given the right environmental conditions.

With this as a common starting point, physiological studies have led to successive revision of what were initially static and relatively simple descriptions of thermal optimization. Caught up in the seemingly endless quest for better understanding of the dynamic relation between bodies and their environments, terms of analysis have been refined, new parameters included and the scope of enquiry extended to take account of, sound, lighting and smell. Exploiting the potential afforded by the latest computer technologies, physiological models are now able to detail the thermal properties of 9,000 parts of the body and to simulate the dynamics of blood and tissue heat transfer as well as the operation of sensations, nerve endings and layers of skin.

To figure out how and why this kind of research has informed the specification of comfort, we need to reflect on the types of questions it promises to clarify and the sort of knowledge it generates.

Questions and Agendas

In *Home: A short history of an idea*, Rybczynski (1987: 220) argues that mass production, industrialization and the possibilities of indoor climate control transformed the meaning of comfort 'not only qualitatively but also quantitatively'. The possibility of manufacturing just about any kind of indoor environment went hand in hand with the ability to control and measure key (reproducible) parameters like those of temperature, humidity, and ventilation. Since nature offered ready-made models of climatic perfection it made sense to use this new found capacity to analyse and reproduce already idealized environments. To begin with, American air-conditioning manufacturers of the 1920s harboured varied ambitions including those of bringing the 'best of the beach' indoors, or recreating the fresh breezes of a mountain resort (Cooper 1998). But which conditions were 'best'? This was contested territory, especially as the idea of indoor climate control conflicted with popular and medical theories about the value of fresh air and natural ventilation.

Thermal comfort research undertaken at the American Society of Heating and Ventilating Engineers (ASHVE) saved the day, leading to the specification of just one ideal climate defined through the quantitative analysis of mechanically reproducible parameters. The 'Comfort Zone', defined by Houghten and Yaglou (from the ASHVE) in 1923, took into account heat and humidity. This specification had a decisive role in closing debate and doing so in a manner that suited the industry's interests. Summarizing the social and commercial importance of this development, Cooper writes as follows: 'The drive for quantitative accuracy was fuelled not only by the need for accurate information on which to build effective designs, but also by the desire to supply engineers with the surety of quantitative values in the rugged debate before the public in general and regulatory agencies in particular' (Cooper 1998: 70). In effect, scientific study of the human body resolved otherwise endless discussion about what engineers and designers should do, how the fledgling heating and cooling industry should be regulated and how competing technologies might be evaluated.

The research-based quantitative specification of comfort had the further, perhaps more significant, effect of creating and shaping markets. For air-conditioning manufacturers the basic challenge was not so much that of meeting human need (whatever that might be) but of turning comfort into a mass commodity and of making it into a consumer product that could be actively promoted, desired and delivered. In all of this, it was an enormous advantage to invoke scientific evidence. And it was even better when such evidence proved that given the vagaries of the weather just about everyone needed the product in question. Cooper puts it precisely: 'When it was shown that no natural climate could consistently deliver perfect comfort conditions, air-conditioning broke free of its geographic limits. When no town could deliver an ideal climate, all towns became potential markets for air-conditioning' (Cooper 1998: 78). In short, the quantification and specification of an ideal and ideally consistent environment, defined in terms of temperature, humidity and so forth, constituted a really significant breakthrough in constructing comfort as a marketable concept and in the normalization of man-made weather.

Physiology – as a discipline – had two qualities that made it ideally suited to the task of specifying comfort *and* of generating conclusions that would apply everywhere and to everyone. First, it took comfort to be a natural condition in the sense that it could be defined and analysed in terms of human biology. Second, it generated precise, quantitative results that were difficult to contest. The science of thermal comfort, as developed from the 1920s on, has had the straightforward ambition of revealing and better understanding natural physiological responses, but the comments above suggest that this is not an entirely neutral enterprise. Reviewing the field in 1993, Nigel Oseland concludes that the knowledge produced by conventional thermal comfort studies is of a type that legitimizes air-conditioning and that relates to the needs of that industry. Research in this tradition is, he says, of little value to those designing buildings to make use of solar energy. Put simply, 'Passive design requires thermal comfort information of a quite different kind, since the interest no longer focuses on thermostat settings, control bands, and cycling times' (Oseland and Humphreys 1993: 35). This observation underlines the extent to which comfort research has revolved around the taken for granted agendas of those who manufacture and specify equipment and the degree to which questions and methodologies correspond. My next step is to show how the resulting models and concepts of comfort have found their way into the real world.

From Laboratory to Design Guide

Ole Fanger was surely not the first to study the components of comfort but his work has been enormously influential in practice (Fanger 1970). Taking Fanger's equation as a kind of case study, this section follows the operationalization of comfort research and its incorporation into design guides and international standards. Inspired by what he refers to as the 'the basic rule of ergonomics' (Oseland and Humphreys 1994: 12), Fanger's stated ambition was to help designers produce buildings that meet users' needs – no easy matter given individual variations of size, sex, age and fitness and given that these factors have implications for metabolic rate and skin area. No one set of conditions will satisfy the physiological requirements of a variety of human-thermal systems (i.e. people) and as buildings are generally occupied by a variety of such persons, compromises must be made.

Tackling this problem head on, Fanger undertook extensive programmes of laboratory-based research with the aim of identifying the 'quantitative conditions' necessary to obtain not perfect but 'optimal thermal comfort'. His research subjects were exposed to different conditions in carefully controlled climate chambers. As well as measuring skin temperature at different parts of the body, their experience of comfort was assessed by means of a standardized questionnaire. Using this instrument, respondents' feelings were recorded on a seven-point scale ranging from hot to warm, slightly warm, neutral, slightly cool, cool and cold. The laboratory environment allowed Fanger to vary and quantify the relative significance of six dimensions including metabolic rate, clothing, air temperature, radiant temperature, air velocity and humidity. Taking subjects' expressions of thermal 'neutrality' to indicate comfort, Fanger used the results of this research to develop a general equation by means of which he contends that it is 'possible, for any activity level and any clothing, to calculate all combinations of air temperature, mean radiant temperature, relative velocity and air humidity, which will create optimal thermal comfort for man' (Fanger 1970: 15).

Providing the six dimensions of comfort can be controlled (again we see that this line of enquiry assumes the use of mechanical heating and cooling), Fanger's equation makes it possible to predict, specify and so design optimal conditions, that is conditions under which most people will report being satisfied or thermally neutral most of the time. This represents a vital step in the translation of science into practice. Before considering the uses to which such equations have been put, I want to highlight three generic features of the approach.

Although comfort is defined both by Fanger and by ASHRAE's Standard 55 – which is based on his work – as 'that condition of mind which expresses satisfaction with the environment' (Fanger 1970: 14) the body is treated as a physiological system. This being the case, the scientist's role is to identify, with as much precision as possible, the objective conditions that engender thermally neutral, or comfortable, responses. Shifting fields a little, MacAndrew and Edgerton criticize the sort of reasoning that characterizes this kind of research. Their extensive cross-cultural study of drunken comportment leads them to challenge the claim that drinkers lose control of themselves because of alcohol's toxic effect on the central nervous system. Arguing that being drunk is a cultural achievement and not simply the result of chemical or neurological change, they reach the following conclusion: 'if we are ever to understand drunken comportment, we must focus on the shared understandings of the nature of drunkenness that obtain among men living together in societies' (MacAndrew and Edgerton 1969: 171). Turned back to the case in question, the implication is that experiences of heat and cold might be similarly mediated through shared understandings, not of drunkenness, but of comfort. But having framed questions of comfort as questions about the relation between the human body and its environment, thermal comfort researchers are unable to acknowledge or accommodate cultural variation. Personal characteristics (and therefore thermal sensations) may differ widely, but the guiding assumption is that experiences of comfort are determined by the same basic principles of physiology.

Second, Fanger's comfort equation is based on an accumulation of data from a large number of individual cases. The process of averaging in order to achieve a norm is extremely familiar, but is again one that deserves a moments reflection. David Armstrong shows how comparable methods helped construct what he refers to as the 'normal' patient. Careful surveying and quantitative analysis made it possible to identify the mean height and weight of children at different stages of their development. With this statistical benchmark in place, deviance and abnormality came into existence along with the 'normal' child (Armstrong 1983). Standardized comfort equations, also built upon averaged data, have similar effect. They too anchor definitions of optimal or 'normal' conditions in a statistical mean. The result is unambiguous but it is also an artefact of the process of its production. When statistical normality is taken to represent normality in the 'real world', the range of practices and conditions that might be so described is inevitably narrowed. This represents a further mechanism through which science 'creates' normality and is again not unique to this field.

Third, it is useful to recall the purpose and context of Fanger's work. Presented as a general theory of comfort, his research was, as he says himself, designed to inform the specification of air-conditioning systems. This orientation, together with the two features just described (namely, the assumption of social and cultural neutrality and the reliance on statistical normalization), are embedded in Fanger's work and in the engineering standards and design guides that depend on it.

From Design Guide to Practice

One reason for focusing on Fanger's research is that it provides the basis for ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy* (ASHRAE 1992). First released in 1966, this standard informs national codes in Australia, Canada, China, Hong Kong, Jamaica, Malaysia, New Zealand, Pakistan, the Philippines, Singapore, South Korea and Thailand (Janda and Busch 1994). Other internationally relevant standards such as ISO 7730 also incorporate Fanger's Predicted Mean Vote-Predicted Percentage Dissatisfied thermal comfort index. Despite sometimes important differences of detail, for instance, the ASHRAE Standard prescribes a range of acceptable temperatures whereas the International Standards Organization (ISO) provides a method for their calculation, all share and reproduce the core assumptions outlined above.

The consequences for the built environment and for sales of heating and cooling equipment have been tangible. Although ASHRAE standards are not mandatory, American engineers and designers are reluctant to waver from them and since 'it is hard to meet the standard's narrow definition of thermal comfort without mechanical systems' (Brager and de Dear 2000: 22), the effects are predictable. Nick Baker is probably right to conclude 'that the very existence of definable standards for mechanically-conditioned building has been the main cause for the proliferation of air-conditioning' (Baker 1993: 130).

Going full circle, the controlled laboratory conditions of thermal comfort research have generated insights and conclusions that have in turn inspired and justified the development of controlled, laboratory-like, environments in the real world. Reporting on a comparative study of workers employed in international style office buildings, de Dear found that Singaporeans and Danes responded in the same way and in a manner perfectly consistent with Fanger's model (de Dear 1994: 130). This perhaps suggests that the model, and the codes and standards derived from it, really do capture and permit the reproduction of universally comfortable conditions. That is one interpretation. Another, and one supported by de Dear's discovery that in their naturally ventilated homes Singaporeans responded 'quite differently and inconsistently with the prediction of these models' (de Dear 1994: 130), is that employees' expectations have changed *because* of the spread of mechanical heating and cooling. It is at least possible that in determining what people 'need', the science of comfort has allowed designers to produce buildings and systems that meet and at the same time create expectations of comfort.

Before jumping to conclusions about the relationship between science, standardization and consumption it is as well to realize that for almost all its history, thermal comfort research has been in a state of increasingly explosive crisis. The next section considers these tensions and their implications for the theory, practice and future of comfort.

Qualifying Comfort

While there are methodological differences between laboratory-based research and that undertaken in the field, the fault lines of controversy do not simply mirror differences between quantitative and qualitative traditions. The terminology of qualification is none the less appropriate because field studies have the common effect of *qualifying*, that is, of complicating, refining and sometimes refuting the view of comfort as a psycho-bio-thermal attribute.

Although undoubtedly dominant, the tradition of physiological research on which ASHRAE and ISO standards are based is not the only paradigm in town. From Bedford's pioneering work in 1936 onwards, teams of comfort researchers have also been studying people in their 'natural' habitats, that is, in homes, workplaces and the open air (Humphreys and Nicol 1998: 991). Whether designed to check the validity of laboratory results or driven by the conviction that the achievement of comfort is at heart a social process, field studies have shown people to be comfortable (or to be more precise, they show that people say they are comfortable in response to standard survey questions) under remarkably different conditions and under conditions that fall way beyond the margins of physiologically specified comfort zones. To give just a few examples, Nicol found Pakistani workers to be comfortable at temperatures of up to 31 ºC (Nicol 1999: 271). At the other extreme, people have reported being comfortable indoors at around 6 ºC during an Antarctic winter (Goldsmith 1960). Focusing on European differences, more recent research described by Stoops indicates that Portuguese office employees are content with a much wider range of seasonal variation (up to 5 ºC) than Swedes who do not expect indoor environments to waver by more than half a degree (Stoops 2001). As Humphreys' (1976) catalogue of field studies suggests, this list could go on and on.

There are two ways of responding to findings such as these. One is to extend the scope of laboratory-based studies in the hope of resolving or at least accommodating observed discrepancies between actual and predicted experience. The other is to treat insights into how people behave in the real world as relevant and revealing data in their own right. Exemplifying the latter approach, researchers at the more radical end of the adaptive spectrum have sought to understand the social, technical and economic dynamics of comfort. Their approach to question 'what makes people comfortable?' and hence what sorts of buildings should be provided, is best illustrated by Humphreys' (1995) article 'Temperatures and the Habit of Hobbits'.

Adaptive Opportunity

Imagining a trip to Tolkein's Middle Earth, Humphreys speculates on the strategies thermal comfort researchers might adopt to discover, specify and recreate optimal environments for members of Hobbit society. While the driving question – how to meet Hobbits' needs? – resembles that which has preoccupied laboratory researchers, Humphreys advocates a more direct approach, starting with observation. 'We would', he says, 'measure the thermal conditions inside a sample of occupied Hobbit holes. We would observe which rooms they most frequented. We might notice in what circumstances Hobbits opened or closed doors and windows or stoked up the fire to control the hole-temperature. We would notice what the Hobbits chose to wear from their enormous stock of clothing' (Humphreys 1995: 3). 'In the course of our enquiries', he continues, 'we would have learned to know a good Hobbit hole when we saw one, and we would have also learned a good deal about the preferences and adaptive strategies of Hobbits in their quest for comfort' (Humphreys 1995: 4). Happily, there would be no need to subject hobbits to 'invasive measurements or tiresome experimental routines' (Humphreys 1995: 4). In practice, ethnographic investigation should generate all one needs to know to produce comfortable Hobbit accommodation.

The key point is that by 'comfortable' Humphreys means an environment that offers sufficient possibilities for adjustment and adaptation: in other words an environment in which Hobbits can *make themselves* comfortable. This way of thinking involves a fundamental conceptual shift. Instead of being defined and analysed as an attribute, comfort is viewed as an achievement. Accordingly, conditions count as comfortable when they offer varied, flexible and socially as well as technically viable means of avoiding discomfort (Leaman and Bordass 1995: 4). The substance of what people, or even Hobbits, count as comfort (or discomfort) is another matter, and one that might be expected to vary with the outdoor temperature as well as with history and culture.

This way of thinking makes sense of otherwise perplexing observations that people adjust to different (and even similar) conditions over time, not just physiologically, but in the sorts of responses and strategies they adopt. Viewed as a dynamic enterprise, the achievement of comfort is here understood as a creative process of trading, juggling and manipulation whether of clothes, activity, and daily routine, or of building technologies like windows and heating systems. From this perspective, movement between contrasting thermal conditions is not necessarily a problem for designers to resolve. It is simply part of inhabitants' ordinary experience. For Heschong (1979) such variation is in fact an important source of pleasure and 'thermal delight'. Brager and de Dear make a similar point, arguing that 'current control strategies typically adopt a building-centred, energy consuming approach that focuses on creating constant, uniform neutrality-conditions which might actually be perceived by some as thermal monotony or sensory deprivation.' (Brager and de Dear 1998: 93). There are, of course, cultural and conventional limits to what counts as acceptable variety, as well as historically specific material, technological and economic constraints and possibilities. In this regard it is relevant to notice that comfort strategies have changed *because of* the diffusion of standardized mechanically controlled conditions. Taking this as an example of everyday adaptation, Humphreys describes the intersection of social and technical expectation as follows:

> if a building is set, regularly, at, say, 22 °C the occupants will choose their clothing so that they are comfortable at that temperature. If enough buildings are controlled

> at this temperature, it becomes a norm for that society at that period of its history, and anything different is regarded as 'uncomfortable', even though another generation might have preferred to wear more clothing and have cooler rooms, or to wear less clothing and have warmer rooms. (Humphreys 1995: 10)

Although sociologically plausible, observations about the relative and social status of comfort present practical problems for designers and engineers. What does the adaptive paradigm mean for them, for manufacturers and for the ability to design and specify conditions in which people are (or can make themselves) comfortable? How can designers cope if meanings of comfort vary so from one context to another? Should ethnographic research be undertaken in advance of *each* new building? Is there any role for ASHRAE guidelines or for other such globalizing standards and if so, what might that be?

Taken to heart, the logic and philosophy of the adaptive approach legitimizes the provision of multiply varied indoor climates. As well as extending and enriching expectations of comfort such a strategy would also promote the thrill of difference. In other fields of ordinary consumption cultural diversity is increasingly valued so why not also in the domain of comfort? More modestly, designers might be encouraged to produce buildings that allow occupants control over their immediate environment and enhance what Baker and Standeven have called 'adaptive opportunity' (Baker and Standeven 1995). Despite advocating a spectrum of more and less challenging responses, proponents of the adaptive model generally agree that existing standards are not universally applicable, that they ignore important contextual influences and that it is misleading to view people as passive recipients of given conditions (Brager and de Dear 1998: 83). The general effect of all this is to favour culturally and climatically specific design solutions and to justify more flexible specifications.

In environmental terms, these are welcome developments for it has long been clear that the maintenance of thermal comfort, as enshrined in ASHRAE standards, is an unsustainably energy intensive enterprise. 'Single-temperature standards' are, claim Nicol and Roaf, 'costly to the economy, to architecture and to the environment' (Nicol and Roaf 1996). Something has to change but since ASHRAE's standards are founded on a bedrock of scientific evidence they cannot be abandoned overnight. What is required, and what adaptive researchers are endeavouring to produce, is an equally 'scientific' body of evidence on which to base and justify design guides that are 'sympathetic to the climates and cultures of the world and sustainable in the energy that they require' (Humphreys and Nicol 1998: 1002).

Adaptive Science

However meaningful and relevant, studies of how people make themselves comfortable in different societies do not generate self-evidently generalizable knowledge of the kind on which the standards making process has come to depend. This presents a number of methodological challenges: what sort of evidence is required to justify revising standards along adaptive lines and is the production of such compatible with the basic tenets of the adaptive philosophy? Can adaptive science filter through from research to design guide and so to practice? Put another way, can what Disco and van der Meulen (1998) call 'cosmopolitan' knowledge be abstracted from necessarily localized studies of convention and habit, and if so, how?

One methodological response is to aggregate. Humphreys' meta-analysis of thirty-six field studies is in this tradition (Humphreys 1976). Researchers have subsequently drawn increasingly detailed volumes of data from what they revealingly refer to as 'field experiments' in an effort to isolate relevant variables through careful sifting and comparison (Brager and de Dear 1998). Such exercises have led to a number of conclusions. Humphreys' analysis indicated that preferred indoor temperatures related to the weather outside. Although not the whole story, this simple insight suggested the possibility and the value of producing standards that explicitly 'link the indoor comfort temperature to the outdoor temperature throughout its seasonal and geographical variation' (Humphreys 1995: 9).

A second response is to develop criteria with which to refine and customize standards to suit specific conditions, fashions and customs. By studying how and when people adjusted windows, fans and clothing in response to change across a range of climatic conditions Nicol and colleagues have sought to produce design guidelines appropriate for the specific culture and context in which they were working. The conclusion they draw from this experience is that it is possible to design internationally applicable methodologies for specifying variable-temperature standards that exploit existing knowledge about clothing and climate related habits (Nicol and Roaf 1996; Nicol *et al.* 1999).

Before considering proposals to revise ASHRAE standards along some of these lines it is worth pausing to take stock of the adaptive sciences. What assumptions and ideas do they carry with them and what might therefore be carried through to the built environment? Three features are especially relevant. First, when comfort is defined as a sociotechnical achievement, the human body is no longer the primary point of reference. What matters more are the conventions according to which people order their environments. By implication comfort, like drinking or drug taking (Becker 1963), is an acquired habit and one equally laden with meaning. Observation of peoples' practice may reveal apparently consistent patterns but these are not to be assumed in advance or extrapolated from the laws of physics and human biology.

Second, although research in the adaptive tradition makes use of statistical normalization – as in laboratory studies individual preferences are averaged and note is take of what those averages are – interpretations are typically qualified with reference to the society or context from which data are drawn. Hence it is possible to show that Pakistanis, on average, prefer different conditions to those favoured by Swedes. Used in this way, averaging has the potential to reveal diversity and expand rather than contract definitions of comfort.

Third, and perhaps most important of all, studies of how people make themselves comfortable are methodologically open-ended. Because there are no variables to control, no prior assumptions need be made about the dimensions of optimization or the components of comfort. Researchers need not confine their attention to those features of the indoor environment that can be mechanically controlled: if people make themselves comfortable by other means, that is just as relevant. In the event, field studies *may* show that the achievement of comfort has come to depend upon air-conditioning but research of this kind does not in itself underpin such developments.

Because of these features the adaptive sciences occupy an uncertain and ambivalent position with respect to the industries of the indoor environment, to standards-making bodies and to the markets that both sustain. Humphreys and Nicol themselves recognize that 'a change in the philosophy behind the provision of thermal comfort will result inevitably in changes in the industry that designs, supplies, installs, and maintains the requisite hardware and software' (Humphreys and Nicol 1998: 1002). Wholesale adoption of the adaptive model might render current standards redundant, perhaps creating demand for new codes with which to specify the range of adaptive opportunities that buildings afford, or for anthropological advice on how to tailor designs to suit specific cultures. In effect, the theoretical framing of comfort as an achievement results in a style of thermal research that is, on the face of it, likely to inform the development of a more varied and a more flexible built environment than that constructed according to current ASHRAE standards.

Adaptive Standards

The prospect of rebuilding concepts of comfort along these lines is some way off, if it happens at all. Yet there are interesting developments afoot. Proposed revisions to ASHRAE Standard 55-1992 include an 'optional method for determining acceptable thermal conditions in naturally conditioned spaces' (ASHRAE 2001: 22). This might not sound like much, especially as it will make no difference to the design of air-conditioned buildings, but the very idea represents a significant breakthrough at the level of theory and approach. In detail, the proposition is to introduce guidelines that take due account of research showing how thermal preferences change in relation to outdoor weather and climate (Brager and de Dear 2000). A second less dramatic move is to remind designers that although it is customary to assume buildings' occupants to be sedentary and to be wearing a certain number of clos (the clo being a standard unit of clothing), this need not be the case.

It is not necessary to go into all the technicalites to appreciate that debate about the nature and character of thermal comfort is opening up. Ideas grounded in concepts of comfort as an *achievement* are filtering into standards making processes traditionally based upon concepts of comfort as an *attribute*. This could easily represent the thin end of a wedge ultimately leading to questions about whether it is in any event necessary to specify the indoor environment. If optimal conditions are a function of a building's form, the services it provides and the climate in which it is placed, might not understanding of these features be enough to produce inevitably variable, but locally meaningful solutions (Nicol and Humphreys 2001: 57)? A further possibility, and one that might also spell the end of thermal comfort standards as they currently exist, relates to the development of indoor climate control. Standards have, remember, been developed to cope with the problem of determining and providing optimal thermal conditions for people who have different physiological needs. But what if people could adjust their own micro-environments according to their own fluctuating requirements? On this point, Humphreys and Nicol (1998) and Fanger agree that 'the ultimate solution . . . is individual control' (Oseland and Humphreys 1993: 11). The notion of providing 'personalized' air is the next logical step (Fanger 2001). This might indeed be the perfect design solution for it places responsibility for the specification of comfort as well as for sustainability and energy consumption firmly in the hands of the user. As usual, the designer's task would be to meet users' needs but this time it is the need for choice rather than for comfort or sustainability that must be met.

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If ASHRAE and ISO standards were to be revised, radically overhauled or even abandoned it probably would be easier to design more environmentally friendly buildings but would such moves challenge or reinforce unsustainable convergence at the level of ideas, that is, in contemporary meanings and expectations of comfort? Advocates of adaptive standards have so far been keen to stress that they facilitate incorporation of 'energy saving strategies *without sacrificing comfort*' (my emphasis) (Brager and de Dear 2000), in other words, without modifying what people have come to expect. As a political strategy this makes sense: if the aim is to change the standards of professional practice it is as well to be as uncontroversial as possible. But in another way, this brings us back to the more fundamental question of how science, standards

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and design – adaptive or otherwise – influence what people think of as comfortable environments.

Constructing Comfort

This chapter has been designed as a case study in the making of need – for comfort and for energy. As such, it began by showing that comfort, defined as a physical condition, was 'invented' in the eighteenth century. Subsequent efforts to specify the properties of comfort have proved controversial despite the fact that being comfortable is represented as a normal and in the case of thermal comfort, natural state of affairs. Nature and science stand in tension with each other throughout the chapter. Scientific understanding of human physiology has resulted in the specification of indoor environments designed to meet human need. Meanwhile, critics claim that the resulting uniformity constitutes an entirely 'unnatural' form of sensory deprivation. Nature is a universally relevant point of reference, but it proves to be a sometimes unreliable and often elusive guide to action. There is, in addition, further ambiguity about the natural or artificial status of an indoor climate that is so completely cut off from the weather outside. Are we to think of ourselves as part of nature or as safely protected from it? There is much less doubt that standard conditions of comfort have been naturalized in the sense that they are now simply taken for granted. Needs have been defined and reproduced in an incredibly precise manner and in a manner that takes no account of the historical variability of indoor climates or the range of conditions in which people of different cultures say they are comfortable. Much of the chapter has been concerned to detail how this has come about.

The notion that there are human needs to be met and that the task of science and engineering is to specify and deliver the required conditions has proved central to the normalization of demand. The specification of human need was Fanger's goal, and the ambition of meeting such needs was the reason for developing and producing standards based on his research. In describing the role of science in shaping practice I have highlighted the commercial benefits of a physiological conceptualization of comfort. Reliance on the sciences of heat transfer, rather than those of anthropology or sociology, has permitted the development of generalized, apparently universal conclusions about optimal indoor environments. Such precise and theoretically transferable specifications have favoured and perhaps been essential for the global diffusion of energy intensive heating and cooling technologies. As a result, a growing portion of the built environment is quite literally constructed around these models and concepts.

In this case, international standards have been powerfully effective media for the translation of research into practice and for the worldwide standardization of technologies, building styles and conventions. As represented here, standards are good not just for regulating and controlling practice but for doing business, building mass markets and creating opportunities on a scale that would be difficult to generate in any other way (Krislov 1997). In short, universalizing types of science are especially well suited to the dissection and specification of human need and to the design and diffusion of standards and standardized commodities purporting to meet these requirements.

As promised, I have offered a relatively conventional analysis of the social construction of indoor climate change, providing a narrative written from the top down and from a largely technological perspective. Although much has been learned about how and why the reproduction of comfort has come to be such a resource intensive enterprise, I have said nothing about what this means for the organization of social life, for what people wear or for how they relate to the buildings they occupy. The next chapter has the dual purpose of taking forward a discussion of the co-evolution of the technologies and practices of comfort and of thinking further about the mechanisms of change and the processes involved.