

Material culture, room temperature and the social organisation of thermal energy

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Abstract

This article builds on the suggestion that objects should be thought of not as bounded entities but as sites of flow, mixture and mutation. In arguing that processes of thermal exchange are outcomes and expressions of socio-material organization, the authors demonstrate the potential for linking concepts from physics and social science. Drawing on a recent study of air conditioning in the UK, they show that increasingly standardised notions of room temperature have implications for product and building design, and for how energy circulates through the many components and bodies involved. In describing indoor climates in these terms, they develop a social analysis of thermal exchange that is relevant at the molecular level and for long-term trends in energy demand and climate change.

Keywords

Energy, flow, indoor climate, scale, thermal exchange

Introduction

Studies of science, technology and material culture routinely focus on the social lives of bounded objects: on how they come to be as they are or their role in sustaining, reproducing or challenging practices of one kind or another. This is important work but, in taking the boundaries of objects for granted, there is a tendency to overlook what Ingold (2007b: 7) describes as the ‘flux in which materials of the most diverse kinds – through processes

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of admixture and distillation, of coagulation and dispersal, and of evaporation and precipitation – undergo continual generation and transformation’. In this article, we take heed of Ingold’s injunction to follow processes of exchange and treat these as lines of enquiry in their own right.

We explore the practical and theoretical significance of this analytic strategy, doing so with reference to a discussion of mechanical cooling and its implications for energy demand and global climate change. In the world of energy modelling, estimates of future trends depend on estimating and evaluating energy demand in abstract terms – that is, in terms that are abstracted from specific configurations of materials, objects and bodies through and around which flows of thermal energy are organised. For example, in estimating future trends in the use of energy for indoor cooling, Isaac and Van Vuuren (2009: 520) expect growth ‘from close to 300 TWh in 2000, to about 4000 TWh in 2050 and more than 10,000 TWh in 2100’: a pattern they attribute to other generic trends, including increasing income.

In this article, we argue for an approach to understanding the dynamics of energy demand that, by contrast, is rooted in a detailed account of thermal exchanges between things and people. More specifically, we suggest that contemporary interactions, at this detailed level, generate a ‘need’ for air conditioning where none existed before. In keeping with this approach, we discuss the arrival of air conditioning with reference to changing processes of thermal exchange, coordinated and arranged around an increasingly standardised notion of normal ‘room temperature’. To date, Ingold’s concepts of flux have been used in describing relations between people and outdoor environments, often with reference to the weather (Strauss and Orlove, 2003); for example, focusing on how snow and ice change ‘the material surfaces of the environment’ (Rantala et al., 2011: 293), or on experiences of living in very rainy climates (Vannini et al., 2012). We work with similar notions of climatic interaction but use them to frame a discussion of thermal relations between people, their possessions and the *indoor* environments they inhabit.

By dissolving analytic boundaries between objects and the air around them we reveal patterns of thermal exchange that operate at radically different scales and that are, in total, crucial for escalating energy demand. The simple observation that flows of thermal energy depend on the social ordering of material is hugely important, we suggest, for understanding and analysing trends in global energy demand, and for doing so in ways that develop and exploit points of connection between physics and social science.

Since air, temperature and thermal energy are not established topics of material cultural analysis, we begin by commenting on how these subjects have been approached in natural and social science.

Conceptualising air and indoor climates

In *The Matter of Air*, Connor (2010) provides an historical review of air as calibrated and known through the methods of natural science, and as defined and experienced by people of different histories, backgrounds and cultures. He describes how physicists and chemists turned air, which is ubiquitous, into a tractable object of enquiry by means of systematic separation, isolation and containment. Such techniques, he says, were vital in constituting air as something that could be described in terms of temperature, humidity,

movement, freshness, pollution and so forth. By contrast, historical and social scientific studies have tended to treat air as an inherently unstable construct, the social significance of which is always on the move. Here, the challenge is usually one of explaining changing representations of air, for instance, as a source of danger, a carrier of disease or a vital aspect of health and well-being. From this point of view, the meaning and significance of air depends on processes of social and cultural association, and the experiences and sensations that follow (Bille and Sørensen, 2007; Corbin, 1986; Jankovic and Barboza, 2009). In both traditions, air is discussed as something that is essentially external to those who encounter it. In other words, air is treated as an object-like entity that has specifiable qualities or that is given meaning and that matters as the medium and context of social practice.

However, this is not the only way to go. In an article entitled 'Earth, sky, wind and weather', Ingold (2007a) considers the weather (and by implication the air) not as the context for human activity but as something that is essentially inseparable from people as living, breathing beings. He writes about it in these terms:

To feel the wind is not to make external, tactile contact with our surroundings but to mingle with them. In this mingling, as we live and breathe, the wind, light, and moisture of the sky bind with the substances of the earth in the continual forging of a way through the tangle of life-lines that comprise the land. (p. S19)

Rather than viewing the air as a 'something' that is experienced, or that has properties of its own, Ingold suggests that we need to find ways of representing and describing processes of mingling and flow. He is evidently writing about the experience of being outside, but people are no less mingled with the environment when they are indoors than when they are out and about. One difference is that, when indoors, the air with which people interact is air that has been confined and that is in many cases deliberately conditioned and managed. From this point of view, an understanding of living as mingling depends on understanding how and why indoor climates are constructed as they are and the forms of thermal exchange involved.

There are intriguing parallels between how physicists represent flows of thermal energy (for example, through radiation, conduction and convection – whether from the human body to its surroundings or the other way around) and Ingold's notions of flux. In technical terms, indoor climates are outcomes of dynamic processes of heat transfer through and between air, people, furniture, fans, heaters, walls, objects, etc. and the components and molecules of which these are made. Inspired by this approach, we bring something like a physicist's interest in thermal exchange to bear on the project of analysing the material culture of indoor climate and the thermal–material relations that characterise its present form.

But as social scientists, we recognise from the outset that indoor climates are not passive outcomes of random thermal interactions. Figuring out how specific configurations come to be as they are consequently depends on a social and historical analysis of the various materials, ideals and standards involved. At different moments and in different cultures, technologies including cast iron stoves (Harris, 2008), openable windows, complex building energy management systems, glass fibre insulation (Guy and Shove, 2000),

woollen clothing and high-backed settles (Humphreys et al., 2011) permit and represent deliberate intervention in what we might think of as the total system of thermal-material culture. From this point of view, the thermal relations to be found in any one setting depend on a combination of past traditions (of practice, construction and material culture) and of more recent arrangements.

Such configurations are important in that the capacity to define and design the thermal properties of an indoor environment and keep conditions stable depends on the capacity to manage (to limit or to enhance) forms of heat transfer within and through that space. Whether or not this requires energy-intensive forms of additional heating and cooling varies from case to case. However, data on energy consumption suggest that the total volume of *deliberately conditioned* space is increasing around the world and that using energy to keep indoor air at a steady 'room temperature', whatever the weather outside, comes at huge environmental cost (Isaac and Van Vuuren, 2009; Sivak, 2009). The usual explanation is that this trend is an outcome of what Roberts (1997) describes as the quest for comfort. In other words, the assumption is that, whenever possible, people will use energy and adopt technologies that allow them to maintain a steady indoor temperature of around 22°C (Shove, 2003).

At best, this is only part of the story. If we take a more relational view of all the thermal gradients of which indoor climates are made, it is clear that we need to take stock of a wider range of more and less conditioned spaces, and take account of dynamic thermal interactions between human bodies and the things these spaces contain. Following this route leads us into a world of material culture in which the thermal interaction between things and their environment becomes the primary unit of analysis and enquiry. In this context, the concept of an 'operating condition' is particularly important in that it defines the 'proper' relation between an object and its surroundings.

Operating conditions for things

Many products are designed to perform or function within a certain temperature range (we focus here on temperature, but other conditions, like humidity, are often important too). Sometimes this range has to do with the chemistry of degradation – for example, emulsion paint needs to be kept in a frost-free environment, ice cream needs to be frozen to stay as ice cream, and many food products are now designed to be refrigerated once the packaging is opened. In other cases, features of efficiency, durability and performance vary depending on ambient operating conditions. For example, if batteries get 'too hot' they have a shorter lifetime than that for which they are designed, and if they are 'too cold' their output drops. Many prescription drugs are also sensitive to temperature: if exposed to 'too high' a temperature their active compounds begin to break down and they become less effective.

In daily life, objects are located in different parts of the home depending on the conditions they 'require'. Moving from the outside in, sheds, garages, cellars, bedrooms, living rooms, larders, refrigerators and freezers have distinctive micro climates, each providing habitats for differently demanding objects. The range of such spaces, and the conditions they afford, is again not haphazard, but is instead bound up with forms of technology, consumption and material innovation. For example, the total amount of

space that is consistently kept below freezing has increased substantially over the last half century, a trend that clearly relates to the emergence of a global system of frozen food provisioning (Garnett and Jackson, 2007; Hand and Shove, 2007).

Understanding the widespread reproduction of an increasingly uniform concept of room temperature is more complex, but it is clear that many objects are now designed to perform best at around 22°C. As mentioned above, batteries can be configured in different ways, but most are produced so that the relationship between power output and durability is optimised for use in a normal indoor climate. Paints, fillers and adhesives are also made to be used at room temperature. When conditions are significantly colder, hotter or damper, such products generally take longer to set or dry and sometimes do not work at all. Similarly, whilst electronic items like computers can and do function across a fairly wide range of temperatures, prolonged deviation from the optimum of 22°C produces thermal strains on components, and collections of components, all designed with room temperature in mind.

As these few cases suggest, ‘room temperature’ is a common point of reference around which flows of thermal energy are arranged and orchestrated. So what is room temperature? Why do so many design and operating standards refer to it, and why 22°C? It turns out that room temperature is itself born of a particular way of understanding the relation between people and the environments they inhabit.

Operating conditions for people

What are referred to as ‘heat balance’ models of human comfort are based on an understanding of how thermal energy is transferred between people and the indoor environment and vice versa. Such models depend on concepts that do not respect the edges either of objects or of people and that are instead concerned with thermal gradients and differentials. In analyses of this kind, people – who figure as one amongst other elements in a much wider system of thermal flow – experience ‘discomfort’ when their bodies either lose or gain ‘too much’ heat from the surroundings. In the language of thermal comfort research, the ‘steady-state heat balance model’ of the human body

postulates a link between the deviation from the minimum load on heat balance effector mechanisms, e.g. sweating, vaso-constriction, vaso-dilation, and thermal comfort vote [this refers to the number of people who say they are comfortable]. The greater the load, the more the comfort vote deviates from zero. (Fountain and Huizenga, 1997: 131)

Ideas like these have informed extensive programmes of laboratory-based research undertaken with the aim of establishing and quantifying the characteristics and qualities of an optimal indoor climate. The results of such studies have been hugely important in that buildings are now routinely designed and engineered to deliver stable conditions optimised for physiological systems (i.e. people) the properties of which are uncomplicated by history or culture. The ambition of reproducing uniform indoor environments is not without its critics (Brager and De Dear, 2003; Heschong, 1979; Shove et al., 2008). Even so, it is increasingly difficult to find new buildings in which temperatures are expected to swing by more than a few degrees. Instead, the normal pattern is one in

which people are encased in a bubble of carefully managed air and in which technologies and products are routinely designed and optimised for such conditions. In this context, innovations that add heat into the system have to be matched by others that extract it.

In the next section, we bring these observations together, focusing on the thermal exchanges and operating conditions that characterise relations between objects (and bodies) within what we might think of as a system of thermal-material culture, doing so as a means of explaining the otherwise surprising diffusion of air conditioning in the UK.

The British climate has not become very much hotter over the last 30 years, but during this period installations of air conditioning have risen dramatically, as they have across Europe. We suggest that trends like these relate to changes in material culture that, in combination, have reconfigured patterns of thermal exchange.

Reconfiguring thermal exchange

As part of our research on 'Keeping Cool' (undertaken within the ESRC-funded Sustainable Practices Research Group), we interviewed a total of 30 people (managers, staff, facilities experts, engineers) working in hospitals, hotels and office buildings that all had air conditioning in one form or another. One intriguing finding was that air-conditioning systems were creeping into organisations that, in general, were against the idea of using energy to keep people cool. Closer investigation of these instances showed that mechanical cooling was 'needed', and often justified, not for reasons of human comfort, but as a means of delivering and ensuring operating conditions required by an increasingly wide range of heat-sensitive technologies.

One case concerned the need for extra cooling in a relatively modern hospital intensive care unit. As our interviewee explained, the unit had gradually become hotter and hotter because new items of specialist medical equipment had been added around the hospital beds, each contributing incrementally to thermal gain. This came to a head during a hot period in the summer when some of the new monitoring screens began to shut down (they are designed to do this when they get 'too' hot). In effect, the accumulation of heat-emitting, but also heat-sensitive, technology generated a crisis of its own making. Since monitoring was vital for patient care, the only possible response was to quickly install more local cooling. In this instance, air conditioning was 'needed' in the intensive care unit because of increasing heat gain and because a previously robust generation of monitoring technology had been replaced with brand-new equipment that was prone to shutting down when the temperature rose.

This is an extreme case but one that is symptomatic of a more general pattern. Another interviewee, this time working in an IT department in an office setting, talked about how specific combinations of 'kit' resulted in a narrow 'operating window', meaning that their computer system as a whole was unable to tolerate much thermal variation. Exactly where the margins of the 'operating window' lie depends on the thermal properties of individual components and on how densely they are packed. For example, adding more hard drives changes the thermal performance of the total system and may 'tip it over the edge' unless steps are taken to extract heat and keep the system cool. Much depends on how high the temperatures actually go but, in general, 'overheating' adversely affects the

reliability of electronic components, reduces their expected lifespan and in some instances invalidates warranties and maintenance contracts.

In the hospital, the monitoring equipment (viewed as a single entity) malfunctioned when the air around it got too hot. In the computer server room, the discussion is of how one component impacts on another and of how additional elements (extra hard drives) might compromise the performance of the whole. In both cases, it is the thermal relation that matters. This can be considered at different scales, meaning that we can think about how 'the computer' relates to the server room, how different bits of kit relate to each other within the confines of the computer's frame, how the elements that constitute any one component are configured, and how molecules are arranged within these elements. Exactly where, when and how thermal energy circulates through such systems is a matter of design (of chips, components, boards, computers, server rooms) and, in that sense, every instance of thermal exchange is an outcome of social/economic as well as physical-material organisation (Chu et al., 2004).

How is it, then, that contemporary arrangements produce situations in which operating conditions are often finely balanced and in which the risk of exceeding them generates demand for mechanical cooling?

Complex electronic equipment can be designed to function in extremely hot environments, as in cars, planes and drilling rigs (Watson and Castro, 2012). The fact that thermal stress is a leading cause of failure/unreliability in computers used in more ordinary settings like hospitals and offices is, in a sense, an outcome of the diverse considerations around which such devices are optimised. Those who make micro-electronic systems confront a succession of heat-related challenges: if they get things wrong, circuit boards can fracture because of differential rates of thermal expansion between one element and another; adhesives holding different components together can give way under such strain, and temperature gradients between components can degrade the thermal performance of the package as a whole (Lall et al., 1997). Exactly how these challenges are handled varies from one product/component to the next and depends, in part, on competing demands of power, weight, cost and size, all of which influence the inclusion, or not, of fans, heat sinks and layouts that minimise hot spots (Kraus and Bar-Cohen, 1995).

Producing a 'good' solution depends on understanding how individual elements create the thermal contexts in which others operate. This is crucial in that it is the overall configuration that determines how heat sources are linked, either by other parts and materials or by the air that surrounds them. From this point of view, it makes sense to think of the ambient air *as part of the device itself*. When the rest of the thermal system is delicately poised it is difficult to accommodate very much variation in room temperature or deviation from standard operating conditions. In this context, it is important to know that computing equipment is typically designed to operate at 22°C, a design point that 'has also been proven to be a generally acceptable personal comfort level' (IBM, nd). In short, computers have been made to 'like' the same room temperatures as those provided for their users and, to some extent, their reliably normal performance depends on the existence of reliably controlled and conditioned indoor climates.

Data centres are now said to account for 1.5 per cent of electricity consumption in the world (Levy, 2012), much of which is used in cooling massive concentrations of heat-sensitive equipment. Another strategy, commonly adopted for desktop computers and

laptops, is to incorporate fans that enable such devices to create micro-climates of their own, as and when required. Guidelines of the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE: 2008) for datacom equipment refers to systems that have

a constant fan flow up to approximately 23°C. Below this inlet air temperature, the component temperature tracks closely to the ambient air temperature. Above this inlet temperature, the fan adjusts flow rate such that the component temperature is maintained at a relatively constant temperature.

There is some debate about whether it is more energy efficient to produce equipment that cools itself or to cool the environments in which it is used, but for us the more pressing task is that of figuring out how the 'needs' of electronic equipment come to be as they are. In tracking back through the forms of thermal interaction involved, we have seen that such demands are reproduced and enshrined in an array of interlocking standards that define the performance of components and products, and the environments in which they are to be used. This interlocking is organised around established specifications of 'room temperature'. The ASHRAE Standard 55, 'Thermal environmental conditions for human occupancy', is used by architects and engineers around the world, and is rightly described as *the* standard for thermal comfort (ASHRAE, 2010). It has become *the* standard to which other standards refer and around which many features of thermal-material culture revolve. In this role, it provides a constant (in every sense) point of reference for product and component design and, as such, is instrumental in establishing and standardising global markets for electronic components, and for heating and cooling technologies alike. For these reasons and more, contemporary operating conditions have become profoundly 'locked in', structuring the social and material ordering of thermal energy at many scales.

In discussing changing thermal relations within hospitals and server rooms, and in trying to explain the 'need' for cooling, we have concentrated on processes of exchange and flow, as physics does, whilst also focusing on the historical and cultural specificity of the matter and the material culture involved. This approach suggests that the demand for air conditioning is best understood as an outcome of the social organisation of (thermal) energy at different scales. More broadly, it points to the relevance of analysing what we might think of as the thermodynamics of material culture.

The social organisation of thermal energy

In this article, we have used a handful of examples, working back from the hospital and office experiences as a means of demonstrating how the social organisation of thermal energy might be examined and explained. In coming to a close, we highlight three key features of our approach.

One is that focusing on processes of thermal flow allows, and in a sense requires, us to see connections between the very small scale (for instance of computer chip design) and the very large: in this case, up to and including the implications of energy demand for global climate change. In the cases we have explored, thermal relations between

electronic devices and the surrounding air and between that air and the human body are currently configured such that operating conditions for things map on to what are thought to be optimal operating conditions for human beings. This historically specific conjunction underpins the need for additional energy to produce and maintain 'optimal' conditions (e.g. through the use of air conditioning), all of which increases overall consumption and related CO₂ emissions. This is only one of a multitude of criss-crossing pathways that, in conjunction, represent energetic movement through the contemporary social and material world. In touching upon how a handful of such relations work out, we suggest that there is scope for developing historical accounts of matter and of thermal exchange, and that enquiries of this kind can help make sense of current trends in global energy demand.

A second related point has to do with the specification of boundaries and edges, for example between a computer chip and the frame in which it is contained, or between the human body and the surrounding air, or between indoors and out. Ingold's (2010: S123) proposition that 'for persons or things to interact at all they must be immersed in the flows, forces, and pressure gradients of the surrounding media' provided a starting point for what has become a rather broader discussion of how heat and, in a more basic sense, energy is organised in society. The methodological strategy of characterising and analysing thermal relations depends on disregarding ready-made object-based distinctions, focusing instead on the forms of intermingling that are involved and on how they come to be as they are.

This brings us to a third feature that sets our discussion apart from those who are primarily concerned to demonstrate the embodied, sensory qualities of intermingled living. As is already obvious, we are interested in matters of substance and detail, that is: in how patterns of exchange and flux take the form they do and in how thermal-material systems are arranged. We have argued that the notion of a normal room temperature of 22°C acts as an orchestrating concept around which other forms of thermal flow are designed and organised. This has not always been the case. To give one small but revealing example, conventional wisdom is that red wine should be drunk at room temperature. Since indoor temperatures have been rising (from 18°C or less to 22°C or more), consumers are now advised to chill red wine to bring it back to the room temperature of the past. This recent re-arranging of thermal relations between wine and room suggests that, on average, 'normal' room temperatures have increased by four degrees or more in less than a generation, and have done so to 'meet' the new standard of 22°C. Meanwhile, the need for refrigeration indicates that 'design' of wine has, in a sense, lagged behind. This example also reminds us that the current configuration of thermal relations has a short history, and flows of thermal energy through and within the material-cultural environment could and perhaps should be organised in other ways.

Current operating conditions and standards appear to foster and sustain arrangements that reinforce the need for precisely controlled indoor climates that are distinctly resource-intensive to maintain. If there is to be any prospect of tackling issues of climate change and energy demand, it is important to think about other options, and to do so on a global scale. From this point of view, the issue is not whether products should be optimised for, say, 18°C rather than 22°C, but whether the tendency to standardise generates

escalating energy demand. There is no guarantee that designing things to operate well in a much more variable indoor climate would be a lower-energy solution overall. While there is unlikely to be one answer to the question of how thermal (and hence social and material) relations should be organised in general, there may well be methods of identifying evidently problematic scenarios. As the hospital example indicated, making and specifying equipment that is optimised for a narrow band of operating conditions sets a scene in which other parts of the thermal-material system (including the heating, the cooling, the human beings and the thermal qualities of the many other objects and technologies involved) have to be configured in such a way that these demands are met. This is quite likely to require further input of energy – in the form of additional heating or cooling.

Situations like these do not arise by accident alone. In considering the forms of thermal lock-in that pertain today we have drawn attention to the commercial interests involved. Like other kinds of standards, operating conditions and specifications of thermal performance establish a level playing field for design and manufacturing. One consequence is that things like computers and their components are produced for a single market (assuming normal room temperature) and are not routinely customised for use in the tropics, or modified for winter conditions. In a still more basic sense, the air conditioning industry itself depends on the existence of a clearly specified set of indoor conditions, so narrowly defined that they can only be met with the help of controlled heating and cooling systems (Cooper, 1998).

To conclude, experiences of thermal sensation and forms of human intermingling with and within indoor climates are not outcomes of some arbitrary flow: rather, they are expressions of a global political economy in which standards and standard specifications have a vital role. More than that, the configurations and conventions with which we are familiar today are themselves born of an age of plentiful energy and of seemingly unlimited potential to calibrate and condition indoor environments without regard to the weather outside. By most accounts, this is not a sustainable arrangement. Thinking about what substantially less ‘energetic’ ways of living might involve depends on thinking about the types of matter, the forms of material culture and the patterns of thermal exchange that future societies might contain. This calls for forms and styles of enquiry capable of representing and exploring processes that do not respect conventional distinctions, such as those between human bodies and the environments they inhabit, or between one bit of material culture and another. Whilst this is relatively new territory, there are relevant resources on which to draw. In stretching notions of human/non-human hybridity, Wallenborn (2013: 152) describes what he calls ‘extended bodies’, constituted ‘through flows including those of air, light, drinks, food, electricity, waves, energy, signs, etc.’. Rather than taking the experiencing body as the central unit of analysis (Myers, 2008; Rantala et al., 2011), his ambition is to characterise fluxes and exchanges as these circulate through the material world. This is a challenging but also productive way to go. As demonstrated above, treating objects and bodies not as static entities but as media of thermal exchange and flow allows us develop a social and historical account of energy demand that moves beyond the study of resources, technologies, objects and their users, and that cuts through micro- and macro- scales of analysis.

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Sam Brown was research associate, employed on the 'Keeping Cool' project of the Sustainable Practices Research Group (SPRG) on which this article draws.