Why ‘automate’ shouldn’t mean ‘regulate’ for thermal comfort in non-domestic buildings

Adrian K. Clear, Sam Finnigan, and Rob Comber

School of Computing Science, Newcastle University

adrian.clear@newcastle.ac.uk

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Abstract

This paper examines how automated HVAC systems and building management policies and procedures shape thermal comfort perceptions, expectations, and energy demand in non-domestic buildings. The empirical basis is qualitative data from interviews and focus groups with building occupants and facilities managers in three UK institutions, recruited in relation to comfort complaints. We argue that 'automation' usually means 'regulation' for building management and the operation of HVAC systems in workplaces, and that this is detrimental for energy demand because it objectivises comfort and reinforces expectations of indoor climate provision.

1. Introduction

Thermal comfort is not uniform, and in this paper we show how the variation in thermal comfort preferences and perceptions in shared work places results in a prevalence of conflict that is escalated rather than mitigated by the automation of mechanical HVAC systems. We see that regulation through automation detaches building occupants from management and control and in doing so it reinforces the centrality of energy-reliant systems in thermal comfort, and diminishes the responsibilities held by building occupants in this regard. We show that during negotiations about thermal comfort in the workplace, the very presence of a control system that provides automation by design opens up the system and the indoor climate to be held fully accountable for thermal discomforts. When occupants find it challenging to express and reach satisfactory resolutions with management for their subjective and situated experiences of discomfort, they look to indoor climate regulations and mechanical system operation for leverage. We relate how systems are held accountable by occupants for inconsistencies in what they promise, algorithmically, and what they provide. In this way, conversations about thermal comfort move from subjective feelings and circumstances to objective setpoints and services, resulting in a mismatch between comfort and energy demand, but also in an increased reliance on energy for comfort.

We argue that we must shift the role of automation away from regulation to loosen indoor climate control and demand a larger role for occupants in thermal comfort. We draw on related work on Adaptive Thermal Comfort (Nicol & Humphreys 2002; Clear et al. 2013) to consider roles for automation that allow for this. We argue that to reduce the energy demand associated with thermal comfort, comfort must be framed differently—as adaptive, rather than tightly specified and bounded—and that acceptance of such framings requires broader changes in organisational cultures, including where responsibility lies in building management. The importance of this for energy demand is even more apparent when we consider the greater extremes in temperature that buildings and their occupants will have to deal in the advent of climate change (Nicol & Stevenson 2013), which could well lead to greater demands on resources to mechanically mitigate them (Shove et al. 2008; Chappells & Shove 2005).

2. Background and Related Work

Many of our workplace environments are controlled in a building-centered manner using mechanical HVAC systems that are energy intensive to run. The strategies for control that are used are based on standards that outline acceptable conditions for thermal comfort. These standards are designed for buildings with central HVAC systems for climate control (Nicol & Humphreys 2009), and—derived from experiments in climate chambers—they prescribe uniform, tightly-controlled thermal

environments in which occupants are passive recipients, and general estimates are made for their clothing and metabolic rates (Brager and de Dear 1998).

Yet, thermal comfort is subjective, and has been shown to be influenced by psychological, as well as physical effects (Luo et al. 2015; Brager and de Dear 1998). Brager and de Dear (1998) showed that occupant's expectations of the thermal environment are perhaps more influential in thermal comfort than behavioural adaptation. Expectations are different for occupants of mechanically controlled buildings compared to free running buildings (Leaman & Bordass 2007), and building occupants with perceived control over their local thermal environment have been shown to have higher thermal satisfaction, and attribute this improvement primarily to psychological influence (Luo et al. 2016). Additionally, participants in Luo et al.'s (2016) study were found to report favourably on even minor temperature changes to their thermal environment when opportunities were provided to modify it.

As buildings are often conditioned tightly to the centre of the "comfort zone" (23˚C according to the ASHRAE standard), occupant desires, expectations and behavioural patterns change for these particular climates (Brager and de Dear 1998), and, ultimately, their role in thermal comfort, i.e. to where they consider themselves "absolved of responsibility" for their own thermoregulation (Fountain 1996). As Strengers (2008) highlights in relation to demand management in domestic buildings, this detachment from management can reinforce the non-negotiability of comfort expectations. This problem is compounded by cultural and corporate "dress codes", such as bankers or executives wearing a warm suit to confer credibility, despite incompatible indoor climates. Opportunities for adaptation are therefore restricted, though schemes such as Japan's Cool Biz campaign attempt to address this through relaxed clothing policies.

In response to these and other shortcomings, an adaptive approach to thermal comfort (Nicol & Humphreys 2009) has been proposed and research has begun to investigate how standards could be modified to account for it (Brager and de Dear 1998). The adaptive approach is premised on a move away from the occupant as a passive recipient of the thermal environment that is provided, to one where they take a more active role in interacting with the person-environment system using opportunities made available to them, in order to achieve comfort (Baker 1996). This might be through personal adjustments (e.g. warm and cool drinks, clothing layers), and the environment (mechanical HVAC control, operating windows and doors). This extra control allows for indoor temperatures to vary more with the outdoor climate, which can have positive impacts both on comfort and energy demand (Milne 1995; Brager and de Dear 1998). In this way, comfort is no longer considered a product of the building, but a goal that the occupant achieves (Shove 2003). Clear et al. (2013) derived strategies for implementing the adaptive model of comfort in conventionally heated buildings. They highlight the 'socially negotiated' nature of thermal comfort and call for more transparency in inter-occupant comfort variation and ways to collectively manage it. In an evaluation of a domestic heating system based on some of these strategies, they found an online forum to be useful for users of the system to communicate with each other, ask questions of the system to reconcile it with their expectations (Clear et al. 2014).

Recent work has begun to investigate the role of Facilities Managers (FM) in reducing energy use. Parag and Janda (2014) treat FMs as middle-actors in organizational energy use and propose a 'middle-out' framework (as opposed to top-down or bottom-up) for understanding and supporting

change. They highlight agency and capacity as important factors in this, both of which come to the fore in our case studies. Goulden and Spence (2015) recently built on this work by identifying the different rationales at play in FM decisions – energy as a cost, energy as a utility, and energy as an implicit right for occupants – and how these can often contradict each other. In this paper, we consider thermal comfort of building occupants in terms of how it is experienced and perceived in relation to building management and control (both organizational and technical, automated and adaptive). We draw on complaints of thermal discomfort to unpack how (lack of) regulation in these processes and the operation of climate-provision infrastructure impacts on occupants' expectations of the indoor climate and thermal comfort. We use these findings to discuss considerations for automation and regulation in bringing about sustainable thermal comfort practices in the workplace.

3. Methods and Participants

In this paper we examine case studies from three different organisations. They each illustrate perspectives of building occupants and management during interactions about thermal discomfort in the workplace. In each organisation, management assisted us in identifying offices to study according to histories of thermal discomfort complaints received by them. We issued a general invite to occupants in these offices to take part in a study that involved talking to us about their comfort experiences in the office. Each of the case study sites is different – e.g. two have automated HVAC systems installed, one of them does not – but they all demonstrate interesting and relevant findings for commenting about the role of automated mechanical systems for heating and cooling office workplace environments, and implications for energy demand.

Our focus on the complaints process provides us with an account of scenarios where occupants are motivated and active in trying to bring about change in their workplace. We examine the mechanisms they use for this, which highlights their perceptions and expectations of workplace thermal comfort, where responsibility lies, and what their role and the role of the organisation and their co-workers are in this.

We name our three case study sites Office2, Office2, and Office3. In each site we interviewed occupants and members of FM. Details of these are presented at the beginning of each case study in the next section. Before the interviews, we monitored the indoor climate using wireless sensors that record temperature, humidity, light, and movement (PIR) for a period of 2 to 4 weeks. Our motivation for doing so was to investigate whether the addition of this data could aid in understanding uncomfortable circumstances, both for management and for occupants, as in all case studies management had expressed uncertainty to us about how to resolve the issues raised. The interviews were semi-structured and they each included some sense-making and a discussion of this data, preceded by questions about perceptions of comfort and experiences of interactions with other stakeholders about discomfort. Interviews were fully transcribed and open-coded for emerging themes. Throughout the paper, we use anonymised pseudonyms to refer to participants.

4. Findings

4.1 Case study 1: drawing on objective guidelines

Our first case study is of a UK university shared office environment (Office1) in which three occupants expressed complaints about heat-related thermal discomfort. Through this case study, we found that the provision of "comfort as a service" to building occupants can be expensive and

difficult to achieve for FM, leading them to favor generalised solutions. However, decontextualizing comfort in this way produces unsatisfactory results, delegitimises subjective experiences and, in turn, compels occupants to frame their complaints and expectations in terms of generalised guidelines and standards. We conducted two interviews – one with the Energy Manager (Peter) of the university, and a group interview with two Office1 occupants (Kate, Alison), and one of their colleagues (Riley) from across the hallway who was called in by them to comment on their situation and to confirm some of their reports.

The University's published Heating Policy states that it maintains an indoor temperature for employees but does not state numerical reference points for this. However, in speaking to Peter about the subject, he noted that, in practice, reference points for heating are used:

"So we would heat between 19 and 23 degrees typically. So it will fluctuate within those boundaries. And it might be that we switch the heating on if external temperatures drop below 15 or 16 degrees or so. That's the sort of switch point for us." (Peter)

Office1 is heated using radiators that are on a district heating system, and controlled by occupants using a Thermostatic Radiator Valve (TRV). It does not have any mechanical cooling system. Radiators were very rarely switched on, and participants complained of overheating throughout the year, which they perceived to be largely due to solar gain – their office contained large, south-facing double-glazed windows. Participant's descriptions of discomfort were quite extreme; they noted a number of physical effects such as lethargy, exhaustion, watering eyes, and allergies.

"I mean, for me, it just makes you that hot you can't breathe properly, it gives you a headache, you know … having to focus on a computer all day as well… by the end of the day your head's just pounding… there's no air in here." (Kate)

Participants reported that they had almost no opportunities at all for adaptation, apart from simply getting out of the office. For example, they had a confidentiality policy that meant that the office door had to be always closed; they could open the windows but usually did not because it was too breezy (the windows could not be placed on a latch and would be blown fully open) and they had problems with bees and wasps in the Summer. The office had a hatch that would be opened during student visit hours, and which relieved discomfort a small amount, but this had to be kept closed at other times to avoid interruption.

The occupants of Office1 had been complaining to the Estates department for over a year about their circumstances. Although Estates agreed with them that it was hot, and informed them that they had investigated various mitigation strategies (including a film to tint the windows), each time they concluded that the respective approach was too expensive. The office occupants were understanding of the financial constraints that Estates were working under but they were equally frustrated that their situation was going unaddressed. Their expectations were of an environment that was appropriate and comfortable to work in and they found it unacceptable that this was not being delivered, whatever the reasons.

"Well everything we're going to get is going to cost, but what's it costing us? You know, being exhausted all the time? They're saying it costs this, it costs that, it costs the other, you can't have it." (Alison)

As a result of the lengthy and unproductive complaint process, the occupants of Office1 felt powerless, and that their opinions were not being valued as an indicator of a problem. When we discussed the situation with them in terms of the sensor data that we collected, they looked for reference points that might provide them with leverage through a more objective measure of their situation. In a previous encounter with Estates, they had queried about guidelines for a healthy work environment but were informed that, while lower bounds exist (e.g. in case heating systems are broken in cold weather), there were no specified upper bounds. In relation to the data that we captured (which was in multiple north and south facing offices in their building), they questioned whether their office temperatures would be considered fair compared to those experienced by their colleagues, and how they compared to recommended guidelines for office temperature.

"Is that… is that 24ish [Celsius], is that considered…. acceptable to be working in? Is everybody else working in that kind of [temperature]?" (Kate)

"So is 26 degrees [Celsius] hot for an office? … [Interviewer explains 19-23 reference used by Estates] … Yeah. So you're over 'comfortable' aren't ya?" (Riley, from across the hall)

Estates' reluctance or inability to respond to subjective comfort complaints led occupants' discussions with us towards numerical values that are decontextualized from actual experiences of the indoor space. Of course, this naturally leads such conversations to foreground the indoor climate, and towards tightly-specified, generalised temperatures common in buildings standards that are energy-intensive to maintain, and that assume a particular dress code, level of activity, and little or no personal adaptation. In this situation, there seemed to be a number of unconsidered opportunities for improving adaptation that could significantly alleviate discomfort.

In our interview with Peter, he seemed to be unaware of the nuanced limitations of Office1's situation (e.g., the need for confidentiality, and ineffective windows). In the occupants' experience, the management process had not allowed for individual and contextualised understandings and solutions. This perhaps related to the need for management to keep solutions within reason, from an expense and an energy standpoint. This includes filtering out issues that are not considered severe enough to warrant a costly change, and assessing implications for implementing solutions more widely across the organisation.

"And there'll also be people that won't accept the information that they're presented with, regardless they'll still want to have whatever they perceive they need. [Fine-grained data] certainly helps because we will be able to respond to a proportion of the population in that building. Show it is what it is, why it is. Show these are factors outside of our control. We can put in systems that can, you know, minimize this or do away with it. But that's costly; we would only need them a small proportion of the year. And we'd have to do it across the campus because, you know, you're not unique. The university isn't going to invest in that so we'd need to find alternative ways of working, we'd need to have adaptation..." (Peter)

In spite, then, of what might be considered a progressive approach to building management from a sustainability perspective, occupant-management interactions that fail to take into account the subjective experiences and nuanced circumstances of occupants can compel negotiations towards energy-intensive retrofits. In this particular situation, while management tried to avoid the use of policies and guidelines that would, in effect, regulate the indoor climate in the workplace, occupants

are surprisingly compelled to draw on such regulations where possible in order to articulate thermal comfort problems in their environment. A failure to handle subjective and localised experiences in the management process serves to reinforce expectations of indoor climate, which, in this case study, management were trying to avoid.

4.2 Case study 2: questioning the mechanical system

Case study 2 demonstrates how, again, unacknowledged subjective experiences and individual circumstances can lead to pronounced expectations – in this case of the operation of mechanical HVAC systems, despite control of the system being given to occupants. Coupled with a lack of opportunities for adaptation, this caused discomfort for occupants and led to complaints that management were unequipped to deal with using existing processes. Office2 is an open plan office in a UK university hosting 20-25 people. The occupants of Office2 are administration and management staff. We conducted a group interview with 4 of these (Thomas, Sarah, Liz, and Emma). Office2 has a HVAC system with 4 vents distributed throughout the office, all of which are controlled by a centralised control unit. This control was originally automated but following on-going complaints that remained unresolved, FM provided control to the office occupants through a control panel mounted on the wall in the office.

Participants told us that the office is widely experienced as uncomfortable, but that perceptions of discomfort vary daily with fluctuations in the indoor climate caused by the operation of the HVAC system. As Thomas explains in the following, the occupants manually adjust the settings of the HVAC daily in order to try to find a balance in temperatures, but in their experience doing so is extremely difficult or impossible:

"I think the major issue is it's two different climates in the same room. So we bring it down to a bit more comfortable and they freeze or, they heat to get warm and we get boiling. So we just can't find a happy medium. And, there's not—there seems to be no fresh air because apparently there's like a sort of difference in opinion about the temperature because some people like it quite hot, but everyone agrees that it's really stuffy." (Thomas)

Participants described the office in terms of extremes, either freezing or boiling; they associated being in the space with lethargy and found it difficult to endure for long periods of time. The main challenge seems to be related to the distribution of the HVAC vents or the positioning of the extractor at one end of the office, which, in practice, leads to one side of the office experiencing chilly breezes when the HVAC is in any setting other than "Heat". The experiences of long periods of cooling seem to be acknowledged as more uncomfortable than the alternative and so there is a general effort to try to minimise the times that the system is not in "Heat" mode, but which results in about half of the office complaining of being too hot.

The adaptive opportunities available to participants were very limited. They could not open the windows. They added and removed clothing layers, but their main scope for adaptation was through control of the HVAC system, which did not provide sufficient scope. Occupants also sometimes left the office to work somewhere else but usually this option was not available to them. They described how their academic colleagues often worked from home, but the same flexibility was not available to them in their roles.

About a year prior to our study, Office2's HVAC was fully automated to maintain 'a nice steady 21' but, following a long process of complaints about very cold conditions due to cooling and air exchange, this was made manually controllable. In the interim, the occupants contacted Estates to adjust the settings on their behalf.

"I was really freezing. Sitting with my fleece on across my legs, and my cardigan and scarf on." (Sarah).

After a lengthy process of unresolved complaints about their current thermal comfort issues, participants felt that they were not being listened to, that Estates did not empathise with their situation, and were frustrated that the negative effects on their wellbeing were going unaddressed. Originally, they reported their qualitative experiences of discomfort to Estates but following no success with subjective and localised accounts of their situation (*"They don't listen to the people who are actually using the office." – Liz*), occupants went on to question the operation of the HVAC system itself with respect to the specified climate that it was designed and set up to produce. In this way, the discussion moved away from contextualised, multi-faceted thermal comfort experiences to objective, mechanically-controlled, stable climates.

"the whole point of the system is that it's supposed to keep at a nice steady temperature, and it never has." (Liz)

Liz uses this framing to critique Estates' judgment and (lack of) action on their case up to now by moving the negotiation from being about the appropriateness of Estates' response to being about the appropriateness of the HVAC system. In order to question the system in this way, participants drew on temperature measurements, both that they had previously recorded themselves, and also the data that we recorded during the study.

"We recorded what our thermometer was saying against the one on the wall, and that's what we sent to reception. And, ours was always much higher than the [setpoint] on the wall." (Liz)

Importantly, for energy demand, we see that the lack of scope for issuing requests and complaints based on contextualised environments and subjective experiences encouraged conversations between occupants and management to move form thermal comfort to climate provision. In the following quote from Liz, there is a suggestion that this also serves to reinforce expectations of indoor environments that are artificially stable and, hence, energy intensive to maintain.

"I just want to be in a room that has got the temperature it's meant to have and no fluctuations, and just nice air circulating around the room and I think, we just need to see that they're (FM) doing that." (Liz)

4.3 Case study 3: from automation to shared control

Office3 hosts two departments of about 20-30 people each in an open plan office. The first is a call centre where employees have fixed desks and use headsets to take calls from clients, and the second is an IT team with a hot desk policy (i.e. desks must be booked for each half day), although participants reported an implicit agreement of a more fixed-desk setup. Our Office3 participants were all from the latter space. Office3 is part of a larger organisation with over 40 premises. It is heated and cooled using three HVAC units. In Office3 we interviewed the Building Manager (Michael), the Carbon Manager of the organisation (Tess), and group interviewed 5 occupants. The

windows can be opened, and are sometimes used, even though participants were aware that HVAC systems work most efficiently in a closed space. Compared to the previous two case studies, the situation in Office3 could be described as one of mild discomfort, but one that has stabilised over time as occupants received manual control of a previously automated system.

The control and upkeep of the HVAC units is the responsibility of Michael, the building manager, employed through an external building management firm. The units are programmable; they take a setpoint and schedule as input. The units also have three different modes: Heat, AutoCool, and Auto. Heat and AutoCool override the setpoint and heat or cool the space, and in Auto the unit works by itself in order to maintain the programmed setpoint. The organisation has a heating policy to maintain an ambient indoor temperature of 22˚C, and the HVAC units were set up to automate this:

"So everything seems to come on now at a steady 22 degrees… and that's what it keeps everything at, so it's all on "Auto 22 degrees" when I come in in the morning, and that's what it stays on all day, supposedly. Or, it should stay on, but obviously I'm getting' the other person comin' in complainin' sayin' 'No, no, I don't like that, it's too cold'… and then you need to tweak it a wee bit…" (Michael)

From a management perspective, the large number of occupants in the office is one of the motivating factors for having an automated and uniform approach to heating and cooling as it limits their abilities to custom-respond to complaints:

Tess (Carbon Manager): The smaller the group, the easier it is to make changes and to try things out, but once you have a big office space like upstairs, it's sometimes easier to leave the air conditioning on because otherwise it's going to be…

Michael: Aye, how many people do I have to ask before I can open this window?

Although the units were originally set to automate a setpoint of 22˚C, as Michael mentions above, he finds himself adjusting them on approximately a daily basis (sometimes twice daily) according to complaints of thermal discomfort from occupants. Depending on who is complaining, and about what, he takes some of the HVAC systems out of "Auto" mode and sets them manually to heat or cool instead. Michael experimented with finding a static, automated setup to achieve this but concluded that a fully automated setting was not achievable without thermal comfort complaints. The main reason for this is because the maintenance of a setpoint temperature requires some cooling, which, for some participants is experienced as an uncomfortable, directed cold breeze that goes unnoticed by others.

Therefore, a large part of Michael's role has become one of responding to complaints by adjusting the configuration of the HVAC system controls, usually overriding the Auto mode to heat or cool parts of the office. Michael no longer views these as 'complaints', rather, he sees it as responding to requests that he has come to expect regularly.

"*After that I gave it up as a bad job… it's never gonna happen, you're never gonna get that perfect temperature all the way through for like a week or a month, so I thought I'll just keep doin' it so it's just a wee tweak now and again but its not too bad a job so I don't mind.*" *(Michael)*

The HVAC controls in Office3 are mounted on the wall of a cupboard that was originally under lock and key. However, for a reason that was not clearly expressed, the cupboard is no longer locked and

other occupants now also take control of the HVAC system. Michael is aware of this situation, and the occupants are aware that they are not permitted access, but through an unspoken agreement they can now adjust the controls themselves without needing Michael to mediate this. Hence, interaction with the HVAC system in Office3 has gone from a fully automated one, to one mediated by Michael, to one where occupants themselves have control over the shared space. It is within this final context that we spoke to participants and learned about their perceptions of thermal comfort and control.

Participants reported variation in thermal comfort with some finding the office space generally too hot, and others finding it too cool. Thermal discomfort due to the cold was often as a result of the operation of the HVAC, in that it sometimes blows cold air to cool and ventilate the room and this affects occupants that are sitting close to the device, without affecting the rest of the office.

"Unfortunately …there's an air conditioner right smack there and it paddles in the afternoon… so the morning's not too bad but in the afternoon it starts doing paddle wavy things and just blows a draught right in to your eyeball." (Tammy)

Overall, participants experienced the indoor climate as variable and fluctuating daily between being uncomfortably warm and cool. Participants that we spoke to ascribed this variation to the adjustments of the HVAC controller by Michael and other occupants. Interestingly, the experiences of shared control seemed to lead to a general acceptance that in a shared office, an ideal "happy medium" cannot exist, and that compromise in the control of the HVAC system and, as a consequence the climate, was required.

"they come and say it's too cold so you go and put the heating on and then they come and say its too hot now and then … I know you're not … see that's the thing, I know you're not going to please everybody, because you've got the likes of Peter that likes it hotter, whereas you've got the likes of…" (Freda)

Compromise was reportedly achieved in two ways. First, taking other occupants into account when making decisions to adjust the settings of the HVAC system. These interactions chime with the notion of 'social comfort' introduced by Cole et al. (2008). For example, Maria notes that if an adjustment is made, it will be a result of an, albeit informal and indefinite, judgement of the comfort of others through a brief observation.

"But that'll be because you have consensus there you'll see how many people are freezing and how many people are not, who are not bothered, and how many people have been […] to wear a jumper, so obviously that's a shared space so that your temperature is controlled by people round about you rather than you personally controlling the ambient temperature […] if there's four of you's who are all freezing then you might be able to make the case to increase the temperature, so that's the way it works at the moment." (Maria)

This approach is somewhat contrary to the previous one where Michael acted as the sole mediator of the HVAC controls. Michael reported that a small number of individuals commonly complained about the temperature, which perhaps was not as representative of the comfort of the office space as a whole. With the previous approach, perhaps the presence of a middleperson meant that individual preference could be more anonymously expressed using Michael as the actuator.

Whereas the latter approach was more inclusive because the act of someone adjusting the settings themselves was observable by everyone else in the office.

The second means of expressing compromise was through personal adaptation. Participants had come to expect that the temperature would not be uniform or consistently comfortable and that they would have to adjust to stabilise their individual comfort by adding or removing clothing layers.

"[the temperature] varies so much through the day that we, you don't know whether or not [it will be hot or cold]. I've learned through all of my other sort of places of work, I just take layers with me, take my cardigans and whatever else" (Orla)

"cause if you're cold you're just going to put another layer on, or put your coat back on." (Isla)

In terms of an adaptive approach to thermal comfort, It is worth highlighting the positive elements of this scenario: expectations in which the lack of an ideal temperature for shared spaces is acknowledged; and personal adaptation. Indeed, this is a direction that we might advocate moving towards from tightly controlled uniform temperatures that are energy intensive to maintain. However, in this case, it is difficult to say that resulting practices are less energy demanding, and perhaps is more likely that demand was increased through inefficient fluctuations between heating and cooling. This scenario leads us to caution against concluding that a move from a fully automated and regulated system to one of looser shared control is more sustainable. In both scenarios, it is the mechanical system that is still foregrounded in the consideration of comfort, and other adaptive opportunities are only employed in the interests of fair use of this. It is interesting then to consider what an alternative approach might be, and where regulation and automation fit in this. Bringing the three case studies together we now conclude with some considerations towards this.

5. Discussion and Conclusions

We presented three case studies that uncover thermal comfort expectations of occupants in relation to their complaints about discomfort. A noteworthy feature of all case studies is that fully automated mechanical control of the environment was not in operation. In Office1, HVAC infrastructure was unavailable, but in Office2 and Office3, the FM had relinquished the previously-automated HVAC systems to manual control due to on-going discomfort complaints. The main reasons for this were that a) the systems did not provide the uniform temperatures that occupants were led to expect (Brager and de Dear 1998), and b) that the tightly-controlled temperatures that these systems strived for were incompatible with the variation in occupant comfort, and this is linked to non-thermal factors (e.g. demographics) that standards do not account for (Brager and de Dear 1998). This latter point represents a prevalence of conflict, which is difficult to resolve if the onus for thermal comfort is placed, in the main, on automated climate provision.

In terms of regulation, these findings are perhaps surprising in that, while management had some form of regulation in place for the indoor climate that was derived from comfort standards, they moved away from these in order to address occupant discomfort. However, importantly, we see that regulation impacted expectations in a more indirect way in Office1 and Office2 as a result of existing management processes not supporting variation in circumstances and preferences of occupants. This delegitimation of complaints served to direct occupant negotiations away from their local experiences of comfort and their specific environment towards heating policies and official guidelines in the case of Office1, and the correct operation of the HVAC system in Office2. As a

result, their thermal comfort demands were framed in terms of the appropriateness of indoor climate that FM provides for them, independent of other factors.

Another noteworthy point is that in both of the offices with HVAC, the HVAC system remained central in thermal comfort practices when under shared, manual control and, as a result, expectations of the provision of an indoor climate persisted. Interestingly, even in Office3 where occupants recounted making use of more adaptive mechanisms for comfort, and being more conscious of the variation in comfort preferences among colleagues, the main focus for achieving thermal comfort remained with the central HVAC system. In fact, it seemed as though thermal comfort was improved with the improved perceptions of control, consistent with findings from Luo et al. (2015), but expectations of the indoor climate narrowed along with the ability to tightly control this, as Alex suggests in the following:

"And if you had a middle ground, neither of us would be happy. Because I would still moan it's a wee bit too warm and she'd still moan it's a wee bit too cold." (Alex)

In line with the adaptive approach to thermal comfort, this leads us to advocate a shift in the role of automation away from regulated setpoints to looser indoor climate control. Such an approach would rely on less energy but require a larger role for occupants to play in achieving thermal comfort. Our case studies point to some important considerations in this transition. First, it is difficult to imagine that lack of regulation is possible, but this might focus more on the provision of low-tech adaptive opportunities as opposed to climate parameters. Secondly, that a fully deregulated mechanical system could result in higher energy demand as in Office3, and conflict as in Office2, and that a more suitable positioning for thermal comfort standards and management might be somewhere between a fully regulated and deregulated one. In practice, we suggest that a major factor in this is the need to engage occupants in an alternative approach where HVAC systems play a much less central role, where compromise on shared climate is necessary, and an acknowledgement that this is a process of transition that requires acclimatisation over the longer term (Brager and de Dear 1998). The role of automation in this scenario might become one of enabling indoor temperatures to more closely track those outdoors. Such an approach would require more open dialogue and communication—termed *interactive adaptivity* by Cole et al. (2008)—to negotiate an appropriate thermal environment among occupants, and between occupants and FM. Finally, our case studies highlight another important role for FM in this: to support subjective experiences and local circumstances of occupants in their management process. The process of acclimatising to an adaptive approach in conventionally heated and cooled buildings will not be a short-term and smooth one and, as we have seen, existing expectations of comfort-as-a-product can be reproduced when confronted with unsympathetic management processes and policies.

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