Are you sitting uncomfortably? A tale of comfort, energy and productivity

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ABSTRACT

Maintaining a consistent indoor temperature causes one of the largest energy demands in UK. UK buildings are famously poorly insulated and expensive to heat and cool. This is set to become ever more challenging in a warming and rapidly changing climate. What if we allowed ourselves to be more uncomfortable and took more charge of our thermal comfort? Wouldn't we then be healthier, more thermally delighted, more productive? Would we not also save energy and related carbon emissions? We offer this provocation, and set the challenge to identify how this should change the role of future ubiquitous environments.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **HCI theory, concepts and models**; User studies.

KEYWORDS

thermal comfort, non-domestic heating, sustainability, ethics, energy saving

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1 INTRODUCTION

How often do you experience rooms that are uncomfortably hot or cold, stuffy or poorly ventilated, yet seemingly offer few opportunities for you to do anything about it [11]? Most of the western world assume two things about thermal comfort: that comfort and air temperature are the same thing, and that indoor environments should be maintained at around 21°C at all times for comfort and health reasons. Much of the rationale for this dates back to climate chamber experiments, dress codes and working practices from 1970s [7]. If heating and cooling systems expend tremendous and often carbon intensive amounts of energy to maintain 'comfortable' indoor temperatures, why are we not all comfortable? Should this still be the approach in a warming climate as we target net 0 by 2050? Even assuming maintaining a consistent temperature were possible, should uniformity of temperature be what we strive for in any case?

2 THE PHYSIOLOGY OF COMFORT

It should not be surprising that we are not all comfortable at the same temperature. Thermal comfort relates to our physiological reactions to maintain our core body temperature [9]. When we begin to feel thermally uncomfortable we are responding to the need to shiver when we are cold, dilate or constrict bloodvessels in our extremities to increase or decrease heat loss, sweat when we are hot, and so on. Not only do individuals vary physiologically, but we are also influenced by changes in our metabolism, what we're wearing, how active we are being, whether we are ill, as well as external factors such as a cool breeze, a pool of warming sunlight, or that hot laptop on your knees! Standards define a comfort score based on air temperature, radiant temperature, air speed, humidity, clothing level and metabolic rate. The insulation level of clothing was benchmarked as a full business suit, and metabolic rate is that of a middle aged white male working at a desk, as was typical only few decades ago. It is not therefore that surprising that these standards overestimate female metabolic rate by as much as 35% [10].

3 ADAPTIVITY

So thermal comfort, or thermal neutrality, can be defined by the fine balance between all these factors not just how warm or cold the air is around us. Each individual will have a different combination of the parameters at anyone moment in time; particularly our clothing and metabolic levels. In the developed world, since the start of the twentieth century we have taken less and less responsibility for our own comfort and become increasingly reliant on heaters, fans, air conditioners and so on, to help make us comfortable. Yet, human beings are innately adaptable, we can open or close windows, add or remove clothing, take hot drinks, go for a walk. In short, we can all play some role in making ourselves more comfortable, providing we are free to leave our desks. If we remove some of the burden on mechanical heating and cooling, there is considerable potential to save energy, as we have previously argued [4, 5]. Indeed, studies suggest that over a day, most people can tolerate fluctuations in temperature of around 8°C [15], particularly if they are empowered to take actions to adjust their personal comfort level. This is the cornerstone of Adaptive Thermal Comfort, and essential to free running buildings [3, 12, 13, 16].

4 FOR HEALTH

Experiencing a wider range of temperatures might save energy, but may even be good for us. Van Marken Lichtenbelt et al. [18] looked at the health effects of short periods of temperature above and below the accepted zone of thermal comfort. At the the point where participants described themselves as just uncomfortable where they were exhibiting NST (NoneShivering Thermogenesis), health benefits noted included increased energy expenditure, more brown fat activity, increased skeletal muscle metabolism, insulin sensitivity, lower blood pressure, cardiac output and increases to the immune system. For insulin sensitivity, they found an improvement in type 2 diabetic subjects of over 40% after a 10 day study, similar to results with prescribed medication.

5 FOR PRODUCTIVITY

More controversially, some work has pointed to increases in productivity dependant on temperature [8]. Increased indoor summer temperatures after the Great East Japan earthquake to save energy suggested a drop in productivity of around 6% [17]. Chang and Kajackaite found a gender divide where women increased their task performance at a higher temperature, as their male colleagues performed less well, suggesting both a link between temperature and task performance, but also potentially a need to differentiate by gender [2].

6 FOR PLEASURE

Finally, experiencing changes in thermal conditions can be pleasurable, a phenomenon known as thermal alliesthesia or more commonly thermal delight [1, 6, 14]. This is the notion that returning the body from a non-thermalneutral state is perceived as comfortable or pleasant, and vice versa [6]. A cooling breeze on a hot day is pleasing, whereas the same breeze on an 'optimal' 21°C day, may make you feel uncomfortable. Embracing the dynamic range of environmental conditions possible throughout a building and physically moving between them, could allow this pleasure to be experienced more often.

7 CONCLUSION

There is certainly an argument that energy is wasted providing unnecessary heating and cooling; this contributes to the substantial energy footprint of modern buildings. More adaptivity and diversity of indoor temperature is linked with energy savings, but also may have health, productivity and even gains in terms of pleasureable thermal experiences. Existing work in Ubicomp focuses on occupancy prediction and setpoint temperatures. Instead, we might argue that we should provide a more diverse, interesting, and healthy set of indoor conditions that vary. Smart environments might make people deliberately uncomfortable for their own good, or enjoyment, or even to make them more productive. This naturally raises interesting issues surrounding governance, who is in control, and which human and non-human actors are responsible. Morally or ethically, is it defensible to make people uncomfortable for their own good, or the good of the employer? We see this as an interesting potential direction for those building technologies for smart environments, assisted living and energy/sustainability reasons.

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