Keep Calm and Carry On: Exploring the Social Determinants of Indoor Environment Quality

Stephen Snow
University of Southampton
Southampton, SO17 1BJ, UK
s.snow@soton.ac.uk

Shre Kuman Chatterjee
University of Southampton
Southampton, SO17 1BJ, UK
skc105@ecs.soton.ac.uk

Anna Soska
University of Southampton
Southampton, SO17 1BJ, UK
a.i.soska@soton.ac.uk

m.c. schraefel
University of Southampton
Southampton, SO17 1BJ, UK
mc@ecs.soton.ac.uk

Abstract
Poor Indoor Environment Quality (IEQ) in office environments leads to worker discomfort and lost productivity. This paper provides a unique perspective into the specifically social determinants of IEQ in naturally ventilated offices and our work toward designing technology that might improve it. Based on 15 qualitative interviews we explore the rituals, practices and negotiations involved in opening windows and thermostat adjustment. We find that a wish to maintain status quo results in workers putting up with discomfort with IEQ factors well before requesting a change. In closing, we introduce our future design work aimed at drawing attention to existing office practices and encouraging a broader participation in negotiations around IEQ factors in the workplace.

ACM 978-1-4503-4082-3/16/05.
http://dx.doi.org/10.1145/2851581.2892490

Author Keywords
Office; practices; productivity; social; air quality

ACM Classification Keywords
H.5.2 User Interfaces: User-centered design

Introduction
Modern day office environments are hubs for the creation of knowledge work. As such, maintaining an office environment that is healthy and conducive to worker comfort and productivity is paramount. In newer buildings, Building Management Systems and smart HVAC systems automate the process of optimising IEQ. However, the majority of the UK's building stock pre-

dates this technology and many UK office workers are responsible for maintaining thermal comfort and adequate ventilation by opening windows or adjusting thermostats. While greater individual control over workspaces has been correlated to greater perceived cohesiveness and job satisfaction [7], inadequate operation of thermostats, windows, doors or other factors affecting thermal comfort or ventilation may lead to poor IEQ outcomes.

Previous work examines the effect of environmental factors on productivity and cognitive function, for example heat and ventilation [4, 9, 10]. Heat stress is linked to decrements in cognitive function in relation to complex reasoning or multi-tasking [4]. High levels of Carbon dioxide (CO_2) caused by inadequate ventilation is linked to reduced productivity, respiratory illness, allergies and asthma [9, 10]. It is also established that people's perceptions of thermal comfort differ and work in thermostat design attempts to predict and model this heterogeneity [1]. Less work is concerned with whether and how social factors influence air quality. For example does social order or rank in a workplace prevent people asking if they can open a window if they feel it is hot or stuffy? How do individual habits, preferences and existing workplace norms influence IEQ in naturally ventilated workplaces? More importantly, can these social factors be leveraged in the development of tools and interventions to raise awareness of IEQ conditions and foster behaviours that lead to better air quality and individual productivity?

Human Computer Interaction (HCI) is excellently equipped for examining these social factors and workplace dynamics [5] and has good form in this area [2, 8]. Mathur et al. [8] for example broadens the focus from the explicit measurement of workplace productivity towards determining which productivity metrics employees themselves find useful and why. Effort has also been spent on prototyping technologies with employees to foster understanding of different office conditions such as ambient displays of levels of suspended particulate matter in offices [2] or situated displays of indoor CO_2 concentrations in classrooms [9]. Wargocki et al. [9] found awareness of high CO_2 led to better window opening practices and thus better ventilation outcomes.

Towards our broader aim of realising more participative, comfortable and productive workspaces, this paper reports on our work towards problem definition: aiming to better understand the social determinants of IEQ in the workplace and ideating technology that might improve it. Based on interviews with workers in naturally ventilated offices, we examine the practices, rituals, assumptions and social order associated with the maintenance and adjustment of IEQ factors in the office. We close by discussing how we might leverage these social factors in designs that bring attention to IEQ in the office, democratize negotiations and potentially lead to better IEQ and productivity outcomes.

Method

We conducted semi-structured interviews with 15 people (9 female, 6 male) working in 8 separate offices in Hampshire, UK. Sampling included cold-calling and emailing companies engaged in knowledge work in the local area. Five participants were university employees including: 3 research fellows- (P1, P2, P5), 2 PhD candidates (P4, P15). Nine were private sector employees working in architecture (P6, P7, P8), accountancy (P9, P10, P11, P12, P13), hardware

engineering (P3) and one split their time between lecturing at a second university and chartered accountancy. All participants worked in offices where employees could open the windows. Ages ranged between 20 and 41 (mean: 30.5, StDev: 5.5). Interviews lasted between 25-40 minutes and started with a discussion on the participants' self-reported contributors and barriers to creativity and productivity. Following this, a transition was made into discussions of their office, the social order in their office, their personal preferences and practices relating to maintaining IEQ factors and whether and how these factors impacted on their work. Attempting a practice-based approach [3], the intention is to understand not only people's behaviours, but how these behaviours constitute and influence rituals and group practices. Then, to understand the effect of such practices on IEQ. Interviews were conducted in or near the participants' offices and offices were photographed for context. Interviews were audio recorded and transcribed verbatim. Transcripts underwent a two-stage process of thematic analysis using manual coding by the research team with quotes arranged into emergent categories and themes. In the second iteration of analysis, the themes were condensed to six key themes. Of these six, here we discuss the four themes directly related to the social determinants of air quality.

Findings

Bad is normal

Strikingly, each one of our participants reported feeling their working environment was (at some point in the day, week, or season) sub-optimal- e.g. too hot, cold, smelly or stuffy. Many participants found their offices too cold at times during winter (P3, P7, P8, P10) or too hot at times during summer (P1, P2, P4, P5, P6, P10, P11). However, answers were often more nuanced. P6's feeling of cold was related to when the fire door at the end of the office was open for ventilation or when her colleagues returned from a lunchtime run and opened the windows. P4 mentioned her office was often stuffy and airless. This was due in part to their consideration of the noise of their conversations carrying across the corridor, so they tended to keep the door shut. In none of these cases, however, was the problem considered severe, despite remarks hinting at potentially significant effect on their comfort: *"Some days in summer, in the afternoons, you'd be struggling to keep your eyes open… [to] sit up straight"* (P6); *"Within half an hour I start feeling sleepy. No sooner do I walk outside, then I feel fresh"* (P2). It emerged from our participants that experiencing sub-optimal working conditions in the office from time to time, were considered a perfectly normal part of working life.

Ownership

A second recurring theme was that of ownership. It became clear through the interviews that the person who sat next to a window was likely to "own" that window. The opening of a window was typically initiated by others in the office sitting away from the window who felt the air was too hot or too stuffy. After feeling uncomfortable for some time, they would then either ask the group for consensus (e.g. *"shall we open a window?",* or ask the window owner directly. In cases where a window owner was away, another colleague would open the window instead. P1 was the only participant proximate to a window who felt uneasy about opening it:

"Usually someone else deals with the windows… I don't really touch the window sill because there's plants on

there and they're not my plants. So I sort of stay away from the window" (P1).

Ownership was less clearly defined for radiator controls. For example in the workplaces of P1, P3, P4, P6, P7, P8, P10, P11 and P14, the boiler was controlled by a director, manager or facilities management representative, meaning that the office occupants had control over the heating only when the boiler was switched on in the first place. In these offices consent would still generally be obtained before making a change, in a similar fashion to the windows. P9 spoke of only *"four at the most"* of his co-workers who were likely to adjust the centrally located thermostat, all of whom would ask the office whether they minded the change. He was unsure, however, if these adjustments were always agreeable to the whole office: *"…because eight or nine of those thirteen rarely comment"* (P9). These polite rituals of obtaining consent before making a change to windows or thermostats could occur up to several times a day. Yet in all but one case, the negotiations were amiable, with P3 the only participant to report tensions or disagreements in negotiations around window opening or radiator operation.

The Gate Keeper

Negotiations around indoor climate were less straightforward in environments where a single person, sometimes external to the office, held the keys to certain thermal comfort factors. This gave rise to a "Gate Keeper" scenario. The respective offices of (P6, P7, P8) and (P3), the workers had control over individual radiators, but someone with access to the boiler cupboard needed to turn on the boiler in the first place before the radiators could be operated. In both these offices, the Gate Keepers (a director or office manager) determined which days the heating system should be switched on. More complicated were scenarios where the Gate Keepers were external to the office, or even external to the company. P2, P5 and P15 worked in a large open plan office. Here the occupants had some control over temperature and air flow by manually opening the windows, but control over the central heating and the exhaust vents in the ceiling were in the hands of the facilities management team:

*"So what we have to do is if it is extremely freezing at my end, I have to send an email to the group's secretary and she will send an email to the security and the Estates and Facilities. And they will open it up, but there is a delay" (*P2)

Similarly, on the floor where P12 and P13 worked, a temperamental air conditioner meant the office was often naturally ventilated. Yet before windows could be opened, permission had to be granted by the Gate Keeper; the Health and Safety Officer (HSO) for the whole building, which was shared by three companies. As such, conditions had to be very poor before the occupants deemed it appropriate to notify the HSO:

"I think she is generally always around the office… but yeah, we can email her to sort of let her know if we're really struggling. It might be that we talk amongst ourselves out on the floor, and say, "Oh, it's really hot." Then, someone will just volunteer and either send her an email or drop down and see her" (P12)

P13, who worked on the same floor but in a different office to P12 did not worry about this permission: *"…if it's that bad, we do [open the windows], we just don't tell [the HSO], bless her"* (P13).

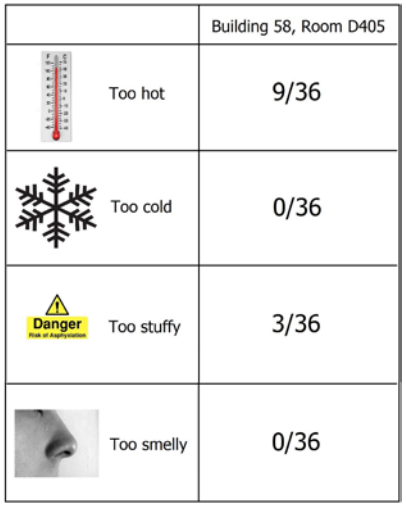

Figure 1: Potential layout of office-situated display

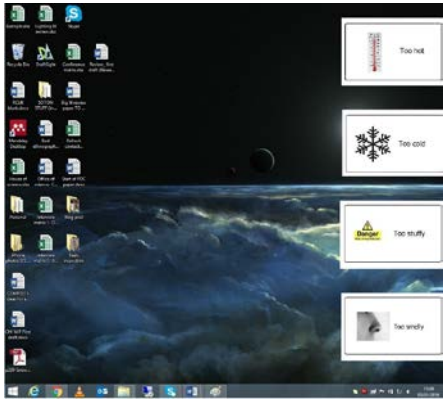

Figure 2: Potential user interface

Discussion

In this paper we have attempted to understand some individual behaviour and group practices in offices [3] and their effects on IEQ. This builds upon prior HCI work concerned with designing for workplace dynamics [2, 5, 8] and represents problem definition work towards our goal of developing social-based tools that help workers in naturally ventilated offices become more comfortable and productive. The findings above shed light on some common social practices of workers in naturally ventilated offices with regard to window opening and thermostat adjustment.

It is apparent in the findings that people accepted their experiences of sub-optimal IEQ conditions as a normal part of working life. Despite this, the interactions between co-workers with regard to window opening and adjusting the thermostat were overwhelmingly amiable. Initially we considered this courteousness and consideration a positive thing, with respect to thermal comfort. Yet by the end of the thematic analysis, we were less sure. Responses indicate our participants seemed to put up with a substantial level of discomfort, e.g. *"really freezing"* (P2), *"really struggling"* (P12) or *"really bad"* (P13) before they would email their building manager, or seek permission from their colleagues to make a change. P1 summed this up: *"Do I suffer in silence? If it gets unbearable, no, but if there's something I can do about it… then I'll do what I can to make that better for myself".* As such, we believe in some cases, polite requests to open a window may in fact be an indication that someone has felt uncomfortably hot, cold or stuffy for a long time and needs some reprieve. Although we do not have the necessary data to back up such a claim, it seems plausible that these workplace norms may be resulting in considerable losses to productivity.

Next steps- tools and interventions

Based on these considerations, we see it necessary to attempt to circumvent the tendency for some of our participants to quietly suffer in silence if an element of IEQ is sub-optimal. We do not believe poor IEQ should be considered a normal thing, and as such, we wish to develop designs that raise awareness and empower, by bringing about a broader participation in IEQ control. As a starting point, we aim to prototype a technology aimed at democratising IEQ negotiations and empowering those less likely to speak up.

Our next design move entails the development of a simple system for continuously gauging subjective experiences of IEQ factors. Occupant satisfaction data would be made available via situated display to be located in a common area of the office (refer Figure 1). This is inspired in part by [9] who prototyped situated displays of CO_2 in classrooms. The intention of the initial deployment is not to quantify metrics of indoor climate (e.g. ℃; % relative humidity; ppm of CO_2), but instead to provide a continuous measure of occupant satisfaction with IEQ through an anonymous poll. The idea behind anonymity stems from some of our participant's reluctance to speak up about poor IEQ. Data for the display would be collected via an intentionally simple desktop interface with four buttons (Figure 2), intended for ease and longevity of use beyond the novelty phase. A desktop-based interface allows for convenience of access, glance-ability, and privacy. A single click log-on additionally provides (in the case of larger offices), an indication to building management personnel of occupancy rates and thus a percentage of the occupants satisfied or dissatisfied with the IEQ at any time. Each

status update (i.e. a click on "Too hot" would last only for 20-30 minutes, to prevent erroneous data resultant from people forgetting to de-activate their status after a change in IEQ. In situations where a "gate keeper" exists, we intend to replicate the situated display on the computer screen of the gate keeper(s) and for this to act as a decision making tool for adjusting vents or thermostats. This functionality may address the situations faced by several of our participants who had to prompt their building manager by email if they were unhappy with an aspect of IEQ. This may lead to quicker response times and a more shared understandings of IEQ factors among building stakeholders.

In the prototyping of such a system, further questions are likely to be raised. For example will such a system actually provide a more accurate representation of comfort, or will people still wait until they are substantially uncomfortable before registering a vote? What is the optimum office size for such an intervention? In smaller offices for example, the anonymity of an individual vote will be more difficult to preserve. To address this, we intend to prototype this intervention first in larger offices and/or those with a "gate keeper" who manages certain IEQ variables. A further consideration for the design of such systems is cultural factors in the design of such systems. For instance, several differences have been observed between the space-heating practices of Japanese versus Dutch people [6]. Although this lies outside the scope of this particular study, cultural practices represent a consideration in future systems of this nature.

Finally, we hope our proposed intervention is not read as an assumption that all IEQ problems in naturally ventilated offices are socially constructed, or can be solved entirely using social methods. In many cases poor IEQ is a direct result of the built environment and require engineering solutions. We also recognise, however, that given peoples naturally differing experiences of thermal comfort [1] and the desirability of control over workplace factors [7], it is likely that negotiations around IEQ activities are likely to exist in a wide variety of office settings independent of building performance. As such, the overall intention of this intervention is not to explicitly solve IEQ problems, but simply to provoke discussions and foster a better awareness of IEQ between building stakeholders. We wish to shine a light on the existing practices and negotiations around IEQ in naturally ventilated offices and to try to circumvent the "keep calm and carry on" mentality when personal IEQ discomfort is experienced. In doing this we hope to work towards more comfortable, participative and productive spaces for the creation of knowledge work.

Conclusions

Through the course of this paper, we have identified (1) that workers normalise experiences of discomfort with indoor environment quality at work; and (2) that social factors may at times delay or prevent people from requesting changes to IEQ factors. To address this, we have outlined our ideas for a simple situated technology aimed at disrupting these norms, generating discussion amongst co-workers and providing a means of better informing building management about occupant satisfaction. Our ultimate goal of creating more participative, comfortable and productive workspaces requires much future work beyond this intervention alone. This includes a better understanding of cultural factors and the suitability of such a system to a range of office types. This is an exciting area of research and encourage others to join us.

References

1. Auffenberg, F., Stein, S., and Rogers, A. (2015). A personalised thermal comfort model using a Bayesian network. In *Proceedings of the 24th International Conference on Artificial Intelligence* (IJCAI'15), Qiang Yang and Michael Wooldridge (Eds.). AAAI Press 2547-2553.
2. Chen, X., Zheng, Y., Chen, Y., Jin, Q., Sun, W., Chang, E., & Ma, W. (2014). Indoor air quality monitoring for smart building. Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '14 2–6. ACM
3. Entwistle, J. M., Rasmussen, M. K., Verdezoto, N., Brewer, R. S., & Andersen, M. S. (2015). Beyond the individual: The contextual wheel of practice as a research framework for sustainable HCI. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 1125-1134). ACM.
4. Hancock, P. A., & Vasmatzidis, I. (2003). Effects of heat stress on cognitive performance: the current state of knowledge. International Journal of Hyperthermia, 19(3), 355–372.
5. Kirkham, R., Ploetz, T., Mellor, S., Green, D., Lin, J.-S., Ladha, K., Wright, P. (2013). The Break-Time Barometer – An exploratory system for workplace break-time social awareness. Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '13, 73. ACM
6. Kuijer, L., de Jong, A. (2011). Exploring practices of thermal comfort for sustainable design. In Proceedings: ACM Conference on Human Factors in Computing, CHI 2011. ACM
7. Lee, S.Y., Brand J.L. (2005) Effects of control over office workspace on peceptions of the work environment and work outcomes. Journal of Env Psychology, 25, 323-333
8. Mathur, A., Broeck, M. Van Den, Vanderhulst, G., Mashhadi, A., Kawsar, F., & Laboratories, B. (2015). Tiny Habits in the Giant Enterprise : Understanding the Dynamics of a Quantified Workplace. Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15), 577–588. AC<
9. Wargocki, P., & Da Silva, N. A. F. (2015). Use of visual CO2 feedback as a retrofit solution for improving classroom air quality. Indoor Air, 105–114.
10. Wyon, D. P. (2004). The effects of indoor air quality on performance and productivity. Indoor Air, Vol 14, 7, 92–101.