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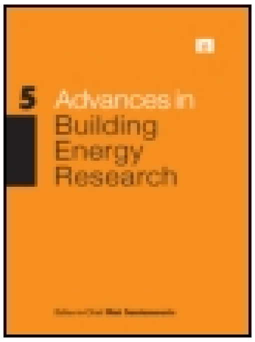

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Office occupants as active actors in assessing and informing comfort: a context-embedded comfort assessment in indoor environmental quality investigations

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ABSTRACT

The energy and building research community acknowledges the importance of including occupants' wellbeing in the evaluation of building energy performance. Particularly in office buildings, occupants' comfort assessment is not yet a common practice, partially due to the shortcomings of the comfort assessment activities. Contextual factors such as the organizational culture, occupants' personality traits and emotional states, and the building and research measurement infrastructures do interact with occupants' motivation to report and influence their actual reporting behaviour. By means of an *in situ* mixed method approach combining real-world research and user-centric methods, this study investigates the impact of a reporting-based comfort assessment. Two buildings, representing different organizational cultures, were selected to study the influence of reporting behaviour on comfort assessment. The buildings were equipped with innovative indoor climate monitoring and *in situ* comfort reporting infrastructure and 2-week field studies were conducted in both buildings. By discussing results from these studies, this paper contributes to the development of building research methodologies of indoor climate and comfort assessment by providing practical experience in embedding comfort reporting behaviour in the analysis of comfort assessment. A contextual typology of reporting behaviour is introduced and its implications regarding the reliability and validity of comfort reporting techniques are discussed.

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In situ and mixed comfort measurement; ; building occupants' reporting behaviour; indoor environmental quality assessment; indoor sensing platform; mixed methods research

1. Introduction

In recent years, research studies on energy use in buildings have shown that often energy efficient interventions often do not meet the initial carbon reduction expected (Azar & Menassa, 2012; Majcen, Itard, & Visscher, 2013). This is partially explained by the influence of occupants' behaviour on the building's performance and the underlying

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need of occupants to maintain a desired level of comfort. However, when estimating the energy reduction of an intervention, occupants' behaviour and their need for comfort are often simplified by using calculated or average values, which underrepresent the complexity of occupant's working and living context. For example, co-benefits or non-energy benefits, such as social well-being, physical and mental health, economic productivity and comfort, and the influence of non-technological determinants, such as occupant's behaviour, culture, and consumer choice and use of technologies, have been indicated as major factors in defining the level of energy demand of buildings' occupants (Sauma, Vera, Osorio, & Valenzuela, 2016; Ürge-Vorsatz, Novikova, Köppel, & Boza-Kiss, 2009). Despite a general acknowledgement from the energy building research community on the importance to include comfort in energy assessments, current efforts to identify and quantify these factors have not yet become a common practice (Dascalaki & Sermpetzoglou, 2011; Fisk, 2000; Roulet, Flourentzou, et al., 2006; Roulet, Johner, et al., 2006). One of the biggest challenges identified is the need for a methodology that on the one hand offers clear standards, while on the other hand embraces comfort as a highly negotiable socio-cultural construct (Chappells & Shove, 2005; Gossauer & Wagner, 2007; Humphreys, 2005) and as a context, time- and subject-dependent assessment (Bluyssen, Aries, & van Dommelen, 2011; Bluyssen, Janssen, van den Brink, & deKluizenaar, 2011; Hauge, Thomsen, & Berker, 2011; Nicol & Roaf, 2005).

A major shortcoming of most commonly used comfort parameters and scales is that they are based on lab research while often applied in real-world setups. Such subjective assessments ignore the influence of the contextual and temporal assignment of the voting activities in the study procedures. Occupants' comfort surveys should be developed as a compromise between goals of the study, needs of respondents, data management and data analysis resources, and the ecological and temporal validity of the data collection methods.

In these advancements, two standards in comfort methodologies are brought forward in this paper: the use of user-centric ICT-supported measurements and the embedment of data capturing conditions in the methodology. First, the adoption of real-world research with a user-centric approach and ICT-supported measurements is considered to enable the collection of accurate and representative data of comfort and other subjective variables (Azar & Menassa, 2013; Batey & Mourik, 2016; Leaman & Bordass, 1999; Leaman, Stevenson, & Bordass, 2010), though limitations and challenges are identified for the design and implementation of real-world and context-depended field studies (Wilson & Irvine, 2012). Evidence from a residential building post-occupancy monitoring (Guerra-Santin, Romero Herrera, Cuerda, & Keyson, 2016) has shown that the adoption of an *in situ* mixed methodology (Romero Herrera, 2017a, 2017b) could generate a realistic and holistic view of occupant's energy consumption by integrating subjective sampling of comfort, attitudes and related practices in the monitoring of post-occupancy. From earlier studies in the office environment (Romero Herrera, Doolaard, Guerra-Santin, Jaskiewicz, & Keyson, 2016), two aspects seem to influence the motivation and behaviour of reporting at work:

- Organizational – The Self-Determination Theory (SDT) in work environments (Gagné & Deci, 2005) describes four extrinsic motivational strategies that nurture the intrinsic motivation of employees to act as citizens in their organizations. Different types of organizational cultures enable different strategies and each strategies shape differently occupant's motivation and behaviour to report. The conscious or unconscious adoption of a strategy depends on (a) the work regulations, in a spectrum from external (controlled-oriented) to integrated (autonomous-supportive) and (b) the personal orientation of employees.

- Socio-technical – Technology-based reporting techniques are promising solutions to increase the accuracy and representativeness of subjective voting, however, participants often experience high burden which limits the possibility of active reporting (for an example, see Gallardo, Palme, Lobato-Cordero, Beltrán, & Gaona, 2016). State-of-the-art building and energy research initiatives have developed technologies that assess occupant's comfort by providing intermediate interfaces to sample it (Balanuta, Pereira, & Silva, 2015; Erickson & Cerpa, 2012; Gao & Keshav, 2013; Jazizadeh & Becerik-Gerber, 2012; Lam, Yuan, & Wang, 2014). These efforts aimed at capturing systematic inputs from occupants, varying from single to complex inputs and even including strategies to automatically capture observable aspects such as clothing and activity levels. These initiatives deserve merits for implementing human sensing in adaptive comfort algorithms, however, the solutions are short term and only locally adopted by research and academic institutions. No discussion is provided with regards to long-term adoption of their strategies and the upscale of the technical solution.

Second, with respect to methodology, a review of post-occupancy monitoring in office buildings indicates a lack of standard procedures as well as a lack of appropriate scales to measure comfort and related factors in field studies (Gossauer & Wagner, 2007). Considering that *in situ* self-reporting in real-world setup is a non-systematic data collection method, a standard description of the reports' distribution and specific behavioural patterns across the study need to be included in the subjective assessment (Brager, Paliaga, & de Dear, 2004; Wagner, Gossauer, Moosmann, Gropp, & Leonhart, 2007). For example, the shape (skewed, normal, constant) of the distribution of reports at different time frames, or the variance of votes between for example consecutive reports, co-located reporters, changes in indoor temperature and other subjective reports, are considered relevant to understand the occupant's motivation and therefore the meaning of the comfort assessment. Also a critical view on the development of appropriate scales is needed. For example, as suggested in earlier work by De Dear and Brager (2002), occupant's environmental assessment should look beyond the traditional comfort assessments that base purely on neutrality ('I feel neither warm or cold') and include richer parameters such as pleasantness ('I feel pleased') to widely address the preferences and need for comfort. Recent proposals have been made to further enrich comfort assessments, like the work of Schweiker et al. (2017) that suggests the development of non-equidistant scales to better capture the subjectivity of votes and avoid the averaging of comfort related factors.

This paper's contribution to the above research discourse is two-folded: first, this paper aims to identify and implement organizational and socio-technical aspects in *in situ* self-reporting methods to influence active and sustained participation and improve the reliability and ecological validity of the measurements. Second, this paper also aims to identify and embed standard description of participants' involvement in the study design (recruitment and communication before, during and after the study) and the actual reporting behaviour to define the appropriate data analysis for the specifics of the study.

The remainder of this paper is structured as follows. In Section 2, the study rationale is described and the BOCS platform and case studies are introduced. Three categories of outcomes are described on Section 3, namely, temperature profiles, comfort profiles and participation profiles of both organizations. This paper concludes the analysis by introducing a preliminary typology of reporting behaviour in Section 4. Section 5 discusses the impact of this typology on the analysis of comfort assessment and identifies implications for the development of integrated energy and comfort assessment.

2. The study

In this section, the study goal and setup is presented, followed by a brief description of the BOCS platform, and an introduction to the case studies and the implementation of the platform in each.

2.1. Study goal and setup

This study design is based on the Sustainability Living Lab (Liedtke, Jolanta Welfens, Rohn, & Nordmann, 2012; Romero Herrera, 2017a, 2017b) methodology and case study methodology (Yin, 2013) to apply user-centric methods with the goal to generate knowledge in the context of *in situ* active reporting in office environments, by:

- describing a typology of office *in situ* reporting behaviour and its relation to the organizational and socio-technical contexts of the building;
- discuss the methodological implications of *in situ* active reporting techniques for the development of an integrated energy and comfort assessment.

Two commercial office buildings participated in this campaign for a period of 1 month, including 2 weeks of self-reporting performed by selected study participants working in these buildings. The chosen office buildings provide rich environments to observe occupants' motivation and behaviours of reporting activities, contrary to the common practice of involving academic establishments, which are considered an advantageous context as scientists are naturally more motivated to participate than other professionals (Wagner et al., 2007). The contexts are investigated as two case studies characterized by similar building infrastructure but different organizational cultures as defined by Gagné & Deci (2005): an autonomous supportive, represented by a flat/flexible organization from a Dutch ICT company (building A) and a controlled-oriented represented by a hierarchical/fixed organization from a UK real estate company (building B).

The case studies were rolled out in sequence based on the availability of equipment and resources: building A study was performed during the month of October 2016 and building B study was performed in the month of November 2016. The study design for each case was slightly adapted to fit the organizational culture and requirements. For a detailed description of each case study and the adaptations, see Table 1. A research assistant (co-author of this paper) was the responsible contact person from the academic institution; a company assistant from each building was assigned to facilitate the recruitment,

Table 1. Design setup.

	Building A	Building B
Study period	13th October to 27th October	3rd November to 17th November
Number of locations monitored[a]	1 floor (15th), 9 sensors (3 in meeting rooms; 6 in open workspaces)	3 floors (4th, 5th and 6th), 43 sensors (8 in meeting rooms; 35 in open workspaces)
Number of participants	Recruited: 23 Dutch nationality	Recruited: 27 British nationality
Participant recruitment	Selected by contact person and by employees themselves; prerequisite – work in the selected floor, own an iPhone or Android phone no older than 5 years old	Selected by the secretaries of the departments; prerequisite – work in one of the selected floors of the building, own an iPhone or Android phone no older than 5 years old
Introduction	Email; first day 'support desk' available at the canteen (3 out of 23 visit the desk)	Email and 1-hour introductory workshop (12 out of 27 attended)
Instructions	Report every time a change in comfort is experienced (suggestion to report 3 times per day)	Report every time a change in comfort is experienced (suggestion to report 3 times per day)
Email reminders	Monday, Wednesday, Friday	Tuesday, Thursday
Means of reporting[b]	Only mobile app	Mobile app and desktop version

[a]Nine locations (4 from building A) with total reports less than the median (16 reports) were excluded from the analysis. In total, 14 locations were included (3 from building A).
[b]Some participants in building B indicated that they do not use their personal phones during working hours. Therefore, a quick adaptation of the mobile app allowed all users to access the same interface through a desktop from day 4.

installation of the platform and execution of the studies. After the start of the study, the research assistant had contact via email with all participants with the purpose to offer support and clarify any question or concern during the study. The research assistant was also in charge of introducing the study and sending the email reminders with the support of a protocol common for both cases:

- The study was introduced as a post-occupancy monitoring project initiated by the company's interest to reduce energy consumption while improving the comfort of its employees.
- The instructions to self-report were communicated as a voluntary activity, with the option to withdraw at any time, to report about their comfort during working hours (a 3 times per day scheme was suggested to spread the reports during morning, noon and afternoon) and every time they feel a change in comfort.
- Printed consent forms were signed by all participants with detailed information on the data collected, how, for how long, by whom and for what purposes the data will be stored, used and published.

The data collection based on a traditional monitoring campaign mixed with *in situ* self-reporting on thermal sensation, noise and pleasantness. Noise and pleasantness are included as extra subjective voting to try out relevant contextual aspects that influence general comfort in the context of shared offices. Another alternative was air quality, but from previous experiences it proved harder for occupants to report on air quality in a simple way, as it depends on multiple factors: humidity, stuffiness, odours, etc.

Data analysis was designed by combining quantitative (primary method: descriptive statistics, correlations and associations, supported by IBM SPSS Statistics for Mac v.2.4) and qualitative methods (secondary method: surveys and interviews; cluster analysis) to analyse objective indoor climate of workspaces, subjective comfort of occupants, and objective and subjective reporting behaviour and experiences.

2.2. The BOCS platform

The BOCS platform (Jaskiewicz & Keyson, 2015) is a socio-technical system that combines indoor climate measurement and occupant's comfort by actively engaging occupants as informing actors. Table 2 describes the main socio-technical elements that interact with the platform.

BOCS (see Figure 1) consists of three main parts: a wireless sensor infrastructure, a web-based self-reporting interface and a visual feedback interface. In this study, only the first two were readily available to pilot in both case studies. A brief description of these two parts follows:

Sensor Boxes and Gateways. The sensor boxes are Arduino-based components that sense the temperature, humidity, CO_2, light and movement. The data sensed is both sent to the nearest gateway, using pocket-sized Raspberry Pi computer extended with a custom Zigbee radio network, as well as stored in a local data storage (SD card) as backup, at 5-minute intervals. The gateways are distributed strategically across the monitored areas establishing a local network between the sensor boxes. Gateways connect to an Internet router that sends the data to a remote central server, where data is processed and stored. The boxes were positioned at the centre of the flexible desks participants work at, outside sunlight exposure. Sensor boxes are numerically identified with a sticker that participants used as input in the self-reporting app. Table 3 summarises the type of data and accuracy of the sensors.

Self-reporting app The Compi app was developed as a web-based mobile app for iPhone and Android devices, and also accessible via a web browser on a desktop computer or laptop. The visual interface offers two interactive screens and one feedback screen that participants are guided through every time they report. A welcome screen is provided with a brief introduction to the self-reporting activity. The first interactive screen asks participants to identify their location by typing the number of the sensor box that is closest to them; the second interactive screen asks participants to assess three comfort variables (pleasantness, thermal comfort, sound level) using graphical scales supported by text descriptors for each value on the scale (see Table 4). The final feedback screen provides real-time feedback of the current temperature of the selected sensor box and the pleasantness and thermal sensation votes reported.

Table 2. Social and technical elements involved in the BOCS platform.

Social infrastructure	Physical/technical infrastructure
Building occupants. Key players in providing and using information; the platform needs to address the abilities and needs of different professions and the working culture of different departments	*Physical layout of working areas*. They influence working and comfort practices; the platform needs to address the influence of different working spaces, e.g. open or closed and flex or fixed areas
Researchers and facility managers. Users of information to analyse and react to the current situation in the building; the platform needs to address different users' goals to access information	*Physical climate infrastructure*. They influence working and comfort practices; the platform needs to address the influence of no/semi/fully automated climate control systems

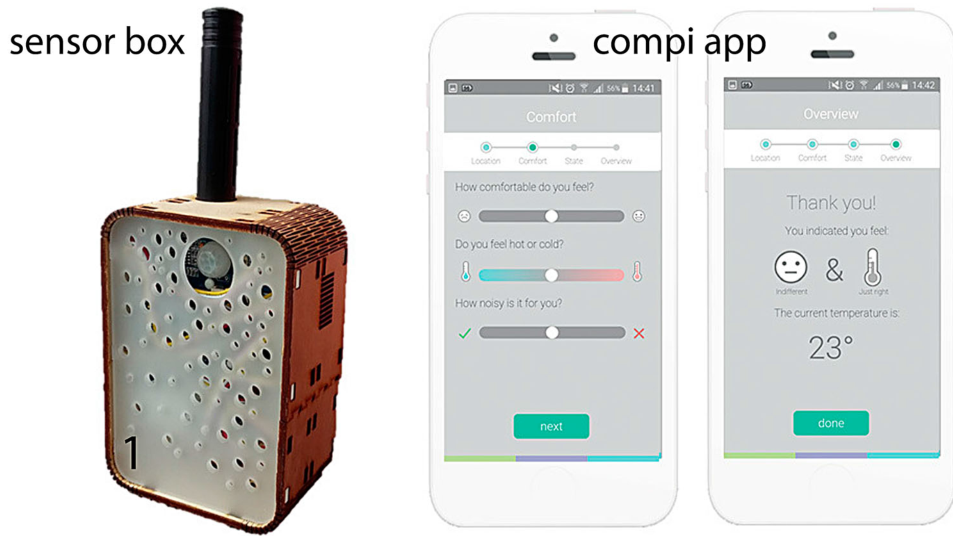


Figure 1. The BOCS platform: the sensor box and the comfi app, a mobile and desktop interface for self-reporting.

Table 3. Accuracy and type of data collected.

Parameters	Measurement range	Accuracy	Resolution
Indoor temperature (°C)	−40 to 80°C	±0.5°C	0.1°C
Relative humidity (%)	5–99%	±5%	0.1%
CO2 level (PPM)	0–2000 ppm	200 ppm	1 ppm

Table 4. Data sources and variables used in the analysis.

Qualitative	Variables	Values
Survey	Experiences with self-reporting	Preferences, suggestions
Email communication	Experiences with platform and study	Issues, complaints
Quantitative	Variables	Values
Self-reported data[a]	Thermal sensation vote	−3 (very cold) · · · 0 · · · 3 (very warm)
	Pleasantness vote	1 (unpleasant) · · · 5 (pleasant)
	Noise level vote	1 (not noisy) · · · 5 (noisy)
Monitored data[a]	Indoor temperature, CO_2, humidity, light and movement	Numeric scale

[a]Analysis focuses on working days (Monday to Friday) and working hours (7–19).

To actively engage participants as informing actors in the assessment of comfort during working hours, a co-design process (Sanders & Stappers, 2008), involving end-users, direct stakeholders and designers, defined the requirements to support continuous and frequent participation: burden-free, to reduce the cognitive effort of reporting; and purposeful, to gain direct benefit from the reporting activity. Previous studies using surveys (e.g. Fabbri, 2016) have identified the importance of keeping the questions simple and basic, while studies aiming to have a sustained involvement of participants across time have identified the importance of providing direct benefit to users for their participation (e.g. Mensink, Birrer, & Dutilleul, 2010). These were translated in a set of design features implemented in the system (see Table 5).

2.3. Case studies

Two case studies were selected with respect to their organizational culture, building infrastructure and involvement in the BOCS project. Figures 2 and 3 show the floor plans of each building and the monitored areas (red boxes). The description of each case is presented in Table 6.

In summary, building A case represents an autonomous, open and social working culture, whereas building B case represents a controlled, open yet individual working culture. Building A supports a bottom up working structure which defines also the type of collaboration and relation with the project; employees participating in the study did so on a voluntary basis presenting an intrinsic motivation and therefore a generally positive attitude towards the studied topic. In contrast, building

Table 5. Strategies to implement a burden-free and purposeful self-reporting interface.

Burden-free	Purposeful
Alternative/optional interfaces to self-report – Flexible protocol to self-report (daily) – Variables pre-set to last input values to optimize the current report	Perception to close the virtuous circle – Access to online visualizations of monitoring and self-report data
E-mail reminders (weekly) – Limited set of variables (and dimensions) to report on	Feedback of reported data and current temperature right after submitting a report

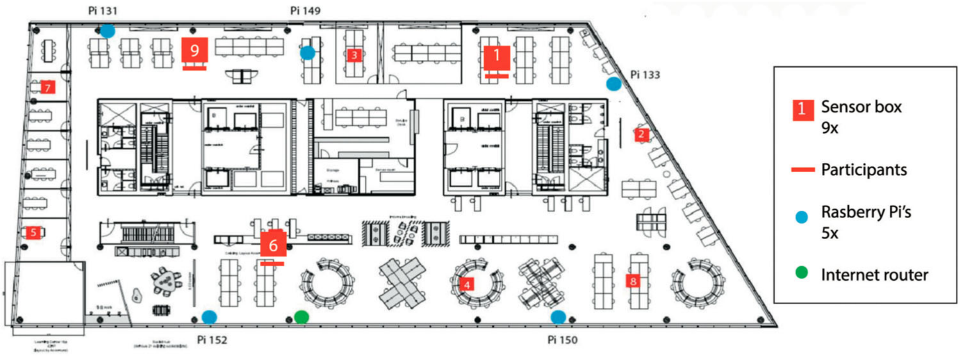


Figure 2. Building A, location of sensors (red boxes). Areas included in the analysis: west area #1 (room 3), #9 (room 85); middle area #6 (room 64).

B supports a top down working structure which also defines the type of collaboration and relation with the project; employees are informed and requested by a member from the organization to participate regardless whether they are interested and positive or not about the project. Table 6 summarizes the description of both case studies.

Table 6. Description of the working culture, infrastructure of each case study.

	Building A	Building B
Working culture	*Business – location*: management consultancy – Amsterdam, the Netherlands *Flexible working style*: 1–2 days working home or other location *Type of work*: collaboration and consultation *Autonomous-supportive*: employees feel responsible for their tasks; they decide when and where to work (as long as the goals are met) *No formal break schedule*: breaks and lunch are important and often social activities *Sustainable responsibility*: company separates garbage and makes employees aware of water usage in toilets	*Business – location*: real state company – London, United Kingdom *Fixed working style*: full-time working at the office *Type of work*: individual tasks mostly *Controlled-oriented*: employees need to show their willingness to work; rushed and busy atmosphere; formal and hierarchical assignation of tasks *No formal break schedule*: breaks and lunch breaks are mostly an individual activity *Sustainable responsibility*: company asks employees to separate their waste
Working infrastructure	*Flexible desk*: open workspace; flex desk (employees select their working area; most of the time is in the same place); use of laptops *Climate control*: modern construction (year 2005), semi-automated building; *Partial control*: automatic lighting system, automatic control of windows and ventilation, adjustable thermostats by $\pm 3^{\circ}$C *Other facilities*; food canteen; meeting and calling rooms; coffee corners; vending machine with office suppliers; terrace with bird sounds	*Fixed desk*: open workspace with fixed desks; use of desktop computers *Climate control*: modern construction (year 2008), semi-automated, providing some control to its occupants: automatic lighting system, automatic control of windows and ventilation, non-adjustable thermostats, adjustable sun blinds *Other facilities*: food canteen; meeting rooms; coffee corner; private working areas
Involvement in BOCS project	*Bottom up*: the company is a non-funded partner of the project; employees have been involved in earlier phases (8 participants of this study); they are able to express questions and concern about the project at all times; they could withdraw from the project at any time	*Top down*: employees have been involved in earlier evaluations of the platform (none of them participated in this study); employees have been requested to participate by the secretaries of their department; they could withdraw from the project at any time

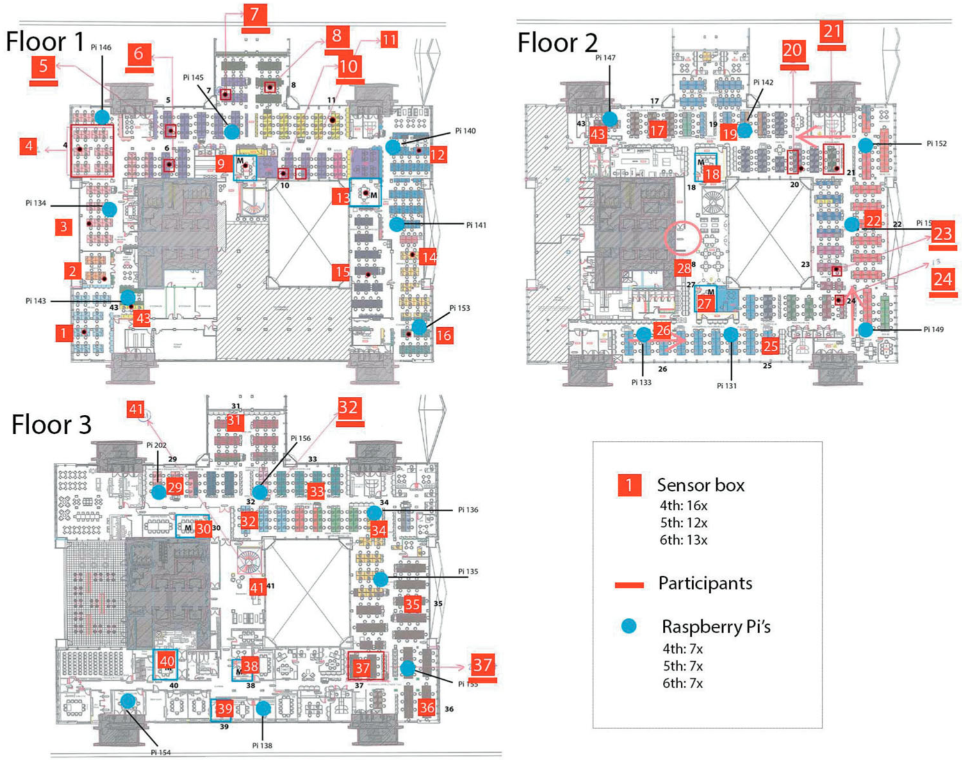


Figure 3. Building B, location of sensors (red boxes). Areas included in the analysis: floor 1 north #5 (4-05), #7 (4-07), #8 (4-08); north-middle #6 (4-06), #10 (4-10); floor 2 north-middle #20 (5-20); east-middle #21 (5-21), #23 (5-23), #24 (5-24); floor 3 north-middle #32 (6-32); east-middle #37 (6-37).

3. Results

The data collected represents a total of 32 days of monitored indoor environmental variables and 20 days of reported comfort variables from both cases. It also includes a total of 24 surveys on participants' motivations and experiences to vote, conducted at the end of the study. Table 7 shows a summary of the data collected including both case studies.

Data analysis considers only working days (Monday to Friday) and working hours (from 7 to 18). The analysis is presented in the following order: description of room temperature profiles, comfort profiles, and room and occupants' participation profile.

3.1. Room temperature profiles

The daily and hourly mean room temperature profiles per building and the histograms per room are presented in Figures 4 and 5 respectively. At first visual inspection, similar and different patterns can be observed within cases (left and middle graphs). Daily mean temperatures are fairly constant across the study period with no significant differences between study days. Hourly mean temperatures are similar across cases, both significantly fitting a quadratic curve with similar coefficients but different constant. The graphs at the right show that daily mean temperatures of all monitored rooms could be clustered in two groups: comfortable rooms with mean temperatures in the range of 21–23 °C and warm rooms with mean temperatures in the range of 23–26 °C . There is a statistically significant difference in mean temperatures between the warm and comfortable groups (even after correcting for the two outliers in the group of comfortable temperatures, room 3 comfort-cold and room 64 comfort-warm). Rooms in the warm group had mean temperatures higher than the comfortable group, 2.08 (95% CI, 1.52 –2.65), $t(12) = 8.003$, $P<.001$. Table 8 presents a summary of the statistics descriptors of temperature in each monitored room (means, standard deviation, minimum and maximum, and quartiles). Light and dark grey tones are used to distinguish the rooms in the comfortable and warm groups respectively. In Section 3.3, further analysis is presented to seek relations between participation behaviour and these two groups.

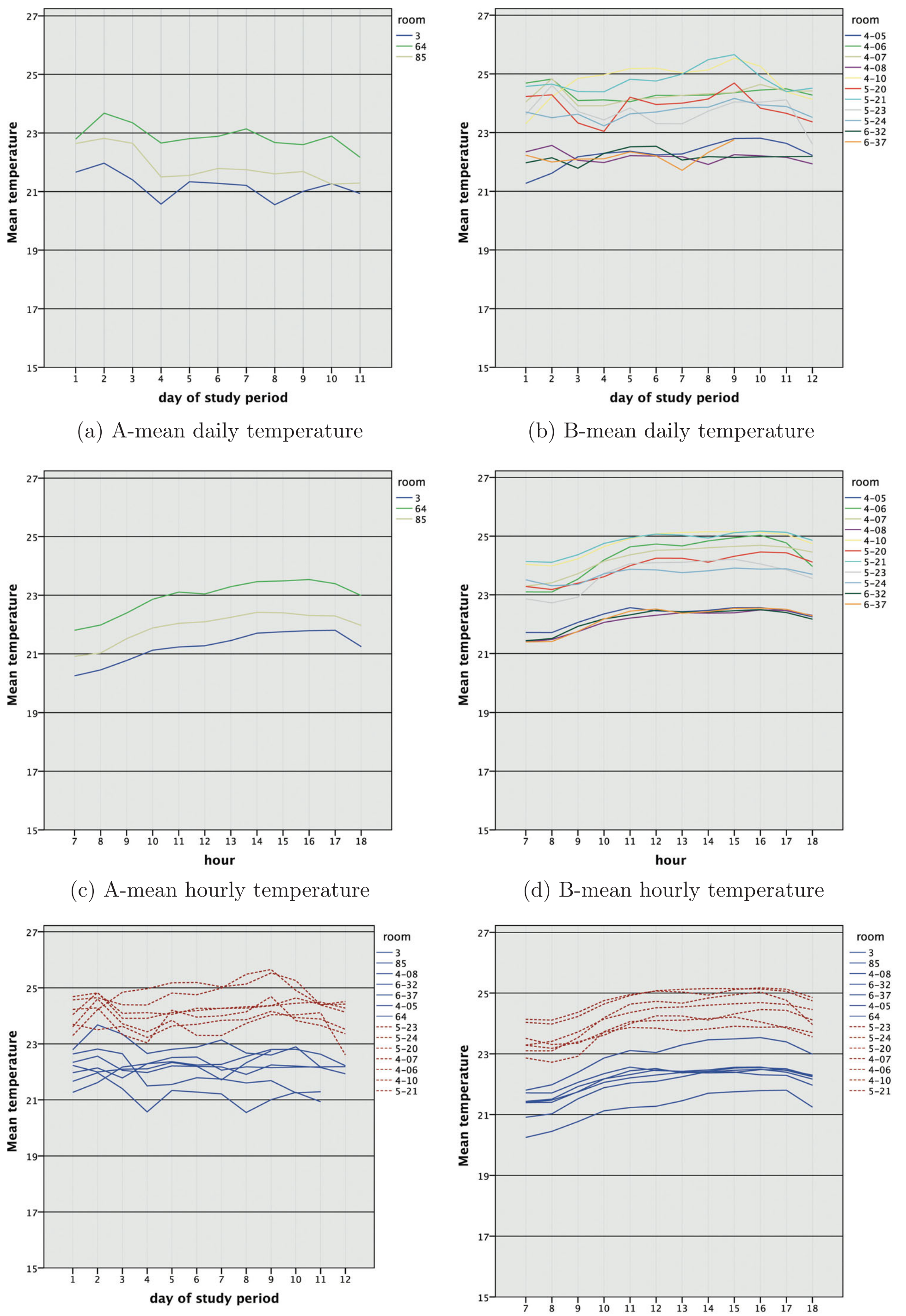
3.1.1. Thermal sensation

Table 9 presents a summary of the statistics descriptors of occupants' thermal sensation in each room monitored (means, standard deviation, minimum and maximum, and quartiles). By calculating the mean value of comfort vote for one degree 'bins' of indoor temperature, Figure 6 visualizes a partial increase of comfort votes with higher temperatures. From Figure 7, it can be observed that regardless of the room thermal profiles, participants

Table 7. Total number of active participants, study days and data collected.

	Building A	Building B
Participants[a]	13 (8 females)	19 (8 females)
Reports	173 (11 working days)	288 (11 working days)
Sensor data	16 days at intervals of 5 min.	16 days at intervals of 5 min.
	3 locations in 1 floor	11 locations in 3 floors
Survey	Debriefing	Debriefing

[a]From the total participants recruited, a reduced number was included in the analysis due to the following reasons: no reports or less than 5 times (9 in building A; 2 in building B); withdrawn (2 in building A, later replaced by 2 others (1 female); 6 in building B, 5 from marketing department due to high workload).



(a) A-mean daily temperature

(b) B-mean daily temperature

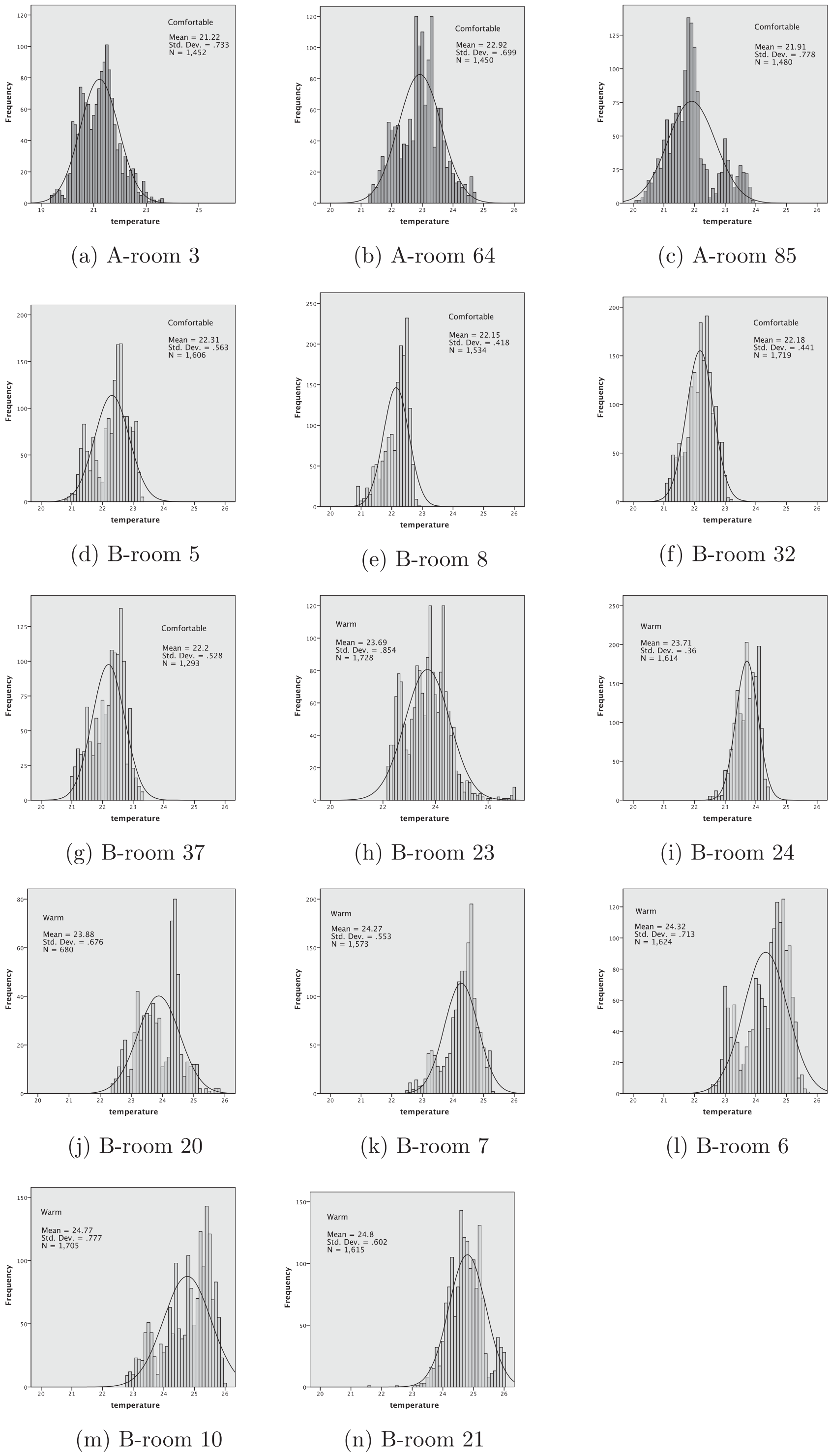
(c) A-mean hourly temperature

(d) B-mean hourly temperature

(e) thermal daily profiles

(f) thermal hourly profiles

Figure 4. Daily (top) and hourly (bottom) temperature profiles per location in Building A (left) and Building B (middle). Right: all locations sorted by mean hourly temperature. (a) A-mean daily temperature, (b) B-mean daily temperature, (c) A-mean hourly temperature, (d) B-mean hourly temperature, (e) thermal daily profiles and (f) thermal hourly profiles.



(a) A-room 3 (b) A-room 64 (c) A-room 85
(d) B-room 5 (e) B-room 8 (f) B-room 32
(g) B-room 37 (h) B-room 23 (i) B-room 24
(j) B-room 20 (k) B-room 7 (l) B-room 6
(m) B-room 10 (n) B-room 21

Figure 5. Histograms of temperatures per office, during working hours and working days. Mean, standard deviation and *N* of monitored temperature are given. (a) A-room 3, (b) A-room 64, (c) A-room 85, (d) B-room 5, (e) B-room 8, (f) B-room 32, (g) B-room 37, (h) B-room 23, (i) B-room 24, (j) B-room 20, (k) B-room 7, (l) B-room 6, (m) B-room 10 and (n) B-room 21.

Table 8. Statistics descriptors (mean, standard deviation, quartiles) of temperatures in each working area monitored.

Location	Mean	Stdev	Min	Max	P25	P50	P75
Building A, room 3	21.22	0.733	19.4	23.6	20.6	21.2	21.8
Building A, room 64	22.92	0.699	21.3	24.7	22.4	23.0	23.3
Building A, room 85	21.91	0.778	20.1	23.9	21.4	21.8	22.2
Building B, room 4-05	22.31	0.563	20.8	23.3	21.9	22.4	22.7
Building B, room 4-06	24.32	0.713	22.5	25.7	23.9	24.5	24.9
Building B, room 4-07	24.27	0.553	22.5	25.3	24.0	24.4	24.6
Building B, room 4-08	21.15	0.418	20.9	22.9	21.9	22.3	22.5
Building B, room 4-10	24.77	0.777	22.8	26.0	24.3	24.9	25.4
Building B, room 5-20	23.88	0.676	22.4	25.8	23.4	23.9	24.4
Building B, room 5-21	24.80	0.602	21.6	26.2	24.4	24.8	25.2
Building B, room 5-23	23.70	0.855	22.2	27.2	23.1	23.7	24.3
Building B, room 5-24	23.71	0.340	22.5	24.4	23.4	23.7	24.0
Building B, room 6-32	22.18	0.442	21.1	23.2	21.9	22.2	22.5
Building B, room 6-37	22.20	0.528	21.0	23.3	21.8	22.3	22.6

Table 9. Statistics descriptors (mean, standard deviation, quartiles) of occupants' thermal sensation in each room monitored.

Location	Mean	Stdev	Min.	Max.	P25	P50	P75
Building A, room 3	4.50	1.106	2	6	4.00	4.50	5.00
Building A, room 64	3.87	1.125	2	7	3.00	4.00	4.00
Building A, room 85	4.63	1.107	2	7	4.00	5.00	5.00
Building B, room 4-05	4.64	.953	3	6	4.00	5.00	5.00
Building B, room 4-06	3.79	1.013	3	7	3.00	4.00	4.00
Building B, room 4-07	3.94	.629	3	5	4.00	4.00	4.00
Building B, room 4-08	3.85	1.226	2	6	3.00	4.00	5.00
Building B, room 4-10	4.39	0.747	4	7	4.00	4.00	5.00
Building B, room 5-20	4.61	0.685	4	6	4.00	4.50	5.00
Building B, room 5-21	4.34	0.684	4	6	4.00	4.00	4.00
Building B, room 5-23	3.94	1.029	3	6	3.00	4.00	4.50
Building B, room 5-24	4.20	0.561	3	5	4.00	4.00	5.00
Building B, room 6-32	4.05	0.887	3	7	4.00	4.00	4.00
Building B, room 6-37	3.91	0.893	1	5	4.00	4.00	4.00

mostly voted 'neutral'. Even more notably, considering that participants in the autonomous-supportive organization (building A) reported from cooler rooms than the majority of participants in the controlled-oriented organization (building B), distributions of votes of participants in building A were skewed to warmer thermal sensation than votes in building B. The left histogram in Figure 7 represents a small skewness (.020) and a negative kurtosis (−.071) describing the warmer sensation of the comfortable rooms compared to the warm rooms. The mid histogram shows a normal distribution of votes (skewness = .020, kurtosis = .701), while the right histogram presents a positive skewness (.941) and a positive kurtosis (1.313) describing a prominent 'neutral' comfort vote distribution despite the 'warm' thermal profile of the rooms involved.

In Table 10 (top), the calculated mean and median of neutral temperatures, indoor temperature and interquartile range per case and room profile are summarized. Neutral temperatures are a subjective concept calculated on the basis of participants' neutral TSV. It can be seen that the means of neutral temperatures fall within the indoor temperature IQR. In addition, the percent of TSV (see Table 10, bottom) shows that only in the warm room profiles 'neutral votes' reached (and exceeded) the 50 % of time that participants reported. This confirms the strong subjectivity of 'neutrality', as occupants adjust

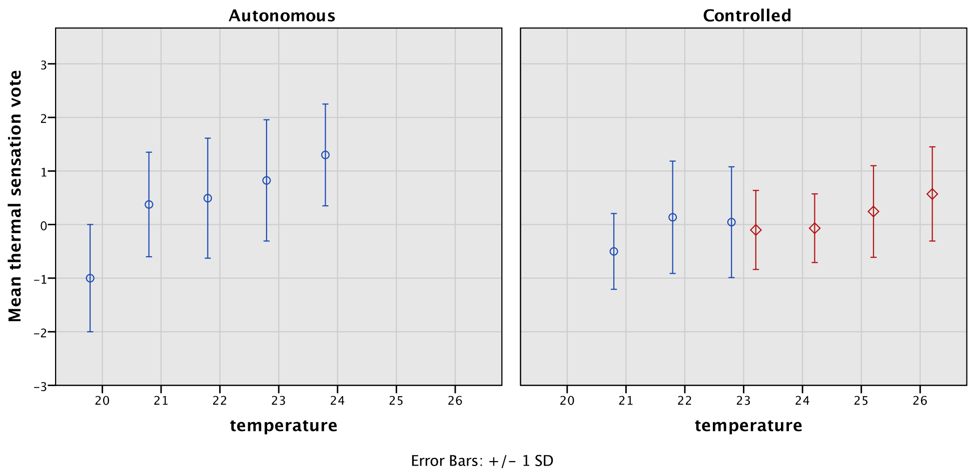


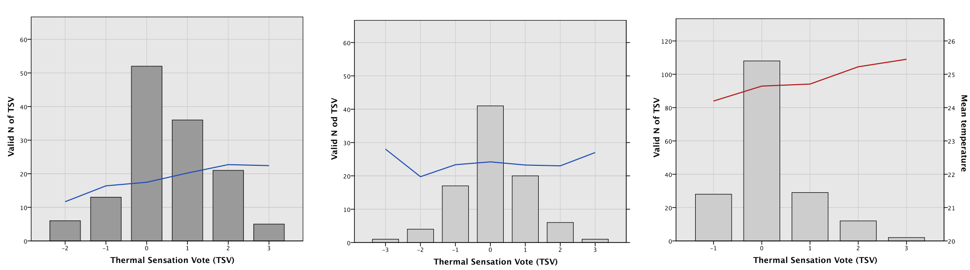
Figure 6. Mean TSV with error bars representing the variation of the mean per 'bins' of 1 degree of indoor temperature; diamonds represent warm rooms.

their thermal comfort sensation with respect to the indoor climate temperature. However, when looking at the warmer sensational votes, there is still a considerable percentage of cases in the group of comfort rooms in which occupants experience warm and very warm thermal sensation (40% in the case of building A and 30% in building B).

3.2. Comfort profiles

3.2.1. Beyond neutrality

Besides TSV occupants reported on two other values: noise level and pleasantness (see Table 4). With the aim to understand their informative value with regards to comfort, both variables were plotted against TSV by splitting the data in two, with TSV $= 0$ as the splitting variable. From noise level, no relations were observed; whereas, as presented in Figure 8, pleasantness shows a partial monotonic relation with TSV. As follow up, two Spearman's rank-order correlation were run to assess the relationship between pleasantness votes and both positive and negative thermal sensation votes. There were negative correlations between pleasantness and negative and positive thermal sensation votes,



(a) Auton-comf (b) Controlled-comf (c) Controlled-warm

Figure 7. Histograms of TSV in relation to indoor temperature: (a) Auton-comf, (b) Controlled-comf and (c) Controlled-warm.

Table 10. Mean and median of neutral and indoor temperature, interquartile range of indoor temperatures, and valid percent table of TSV for culture/thermal profiles.

Profile (N)[a]	Mean t_n (sd)	Median tn (sd)	Mean t_i (sd)	Median t_i (sd)	IQR_i
A/c (133)	21.75 (0.79)	21.75	21.89 (0.87)	21.80	21.3–22.9
C/c (90)	22.42 (0.35)	22.50	22.36 (0.40)	22.40	21.9–22.6
C/w (179)	24.64 (0.76)	24.65	24.63 (0.74)	24.60	23.7–24.8

	−3	−2	−1	0	1	2	3
A/c (133)		4.5	9.8	39.1	27.1	15.8	3.8
C/c (90)	1.1	4.4	18.9	45.6	22.2	6.7	1.1
C/w (179)			15.6	60.3	16.2	6.7	1.1

[a] 13 votes were associated to missing monitored data, so they are excluded from this table.

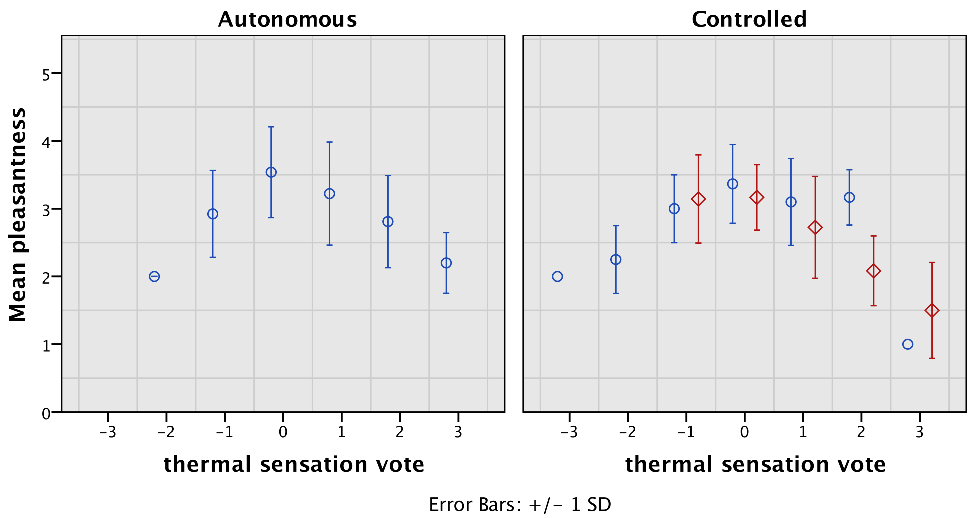


Figure 8. Means of pleasant votes calculated for each thermal sensation vote; diamonds represent warm rooms.

with $r_s(67) = -.295$, $p<.05$ and $r_s(344) = -.359$, $p<.001$, respectively. This indicates that either thermal sensation affects pleasantness or vice versa. A future study is needed to understand causality and therefore provide explanation of one value by the other. In this case, if pleasantness explains thermal comfort, it would mean that low and high TSV values are related to a level of unpleasantness.

3.3. Occupants' participation profiles

Participation profiles are discussed considering both organizational culture and room thermal profiles. The aim is to describe the influence of cultural, thermal and study design factors on reporting behaviour. Occupants' participation profile is defined by the number of daily reports per participant and it can be visually inspected in Figure 10: at the left, with the daily contribution of each participant; at the right, with the total contribution of each participant. Table 11 shows the statistical descriptors of number of reports for each room.

Daily number of reports were ranked in four categories depending whether they met the following criteria: three reports per day ('mid'), below three reports but not zero

Table 11. Statistics descriptors (*N*, mean, standard deviation) of participation profile in each working area monitored.

Room	*N* reports	*N* partic.	*N* days	Mean daily reports (stdev)[a]	Mean daily reports (stdev)[b]
Building A, room 3	30	5	8	3.75 (2.96)	2.73 (3.04)
Building A, room 64	15	4	8	1.88 (0.99)	1.36 (1.21)
Building A, room 85	88	7	11	8.00 (4.31)	8.00 (4.31)
Building B, room 4-05	22	1	9	2.44 (0.88)	1.83 (1.34)
Building B, room 4-06	29	2	11	2.64 (1.50)	2.42 (1.62)
Building B, room 4-07	31	1	11	2.82 (0.40)	2.58 (0.90)
Building B, room 4-08	20	1	11	1.82 (0.87)	1.67 (0.98)
Building B, room 4-10	33	2	10	3.30 (1.49)	2.75 (1.86)
Building B, room 5-20	28	2	7	4.00 (1.83)	2.33 (2.46)
Building B, room 5-21	35	3	11	3.18 (2.48)	2.92 (2.54)
Building B, room 5-23	17	1	8	2.13 (0.99)	1.42 (1.31)
Building B, room 5-24	15	1	10	1.50 (0.53)	1.25 (0.75)
Building B, room 6-32	20	1	8	2.50 (1.20)	1.67 (1.56)
Building B, room 6-37	32	3	11	2.91 (1.30)	2.67 (1.50)

[a]Mean and std dev values considering only days with one or more reports (*N* days).
[b]Mean and std dev values considering full study period (11 and 12 days for building A and B, respectively).

('low'), above three reports ('high') and the 'null' category for zero reports per day. Non-parametric tests were used to determine if there were differences among the categories within cultural profiles (Sign test) and between (Mann–Whitney *U*-test).

Within the cultural profiles, the sign tests indicated differences in reporting behaviour for both organizations, in which the 'mid' and 'high' reporting categories elicited lower number of reporting days compared to categories 'null' and 'low', all a statistically significant increase (see Table 12(I)); similar results were obtained within thermal profiles (see Table 12(II)). When looking at 'low' with the 'null' categories a difference between cultures is observed. For the controlled-orientedorganization (C), the 'low' reporting category elicited an increase compared to the 'null' category (non-statistically significant); whereas for the autonomous-supportive organization (A) a statistically significant decrease in the median of differences in reporting categories was observed (a decrease was also observed for the comfortable rooms while no changes were observed for the warm rooms, both without statistically significant results). Finally, comparison between 'high' and 'mid' categories showed a statistically significant positive difference of the medians for the controlled oriented organization only and consequently, in the thermal profiles similar results were obtained for the warm rooms only.

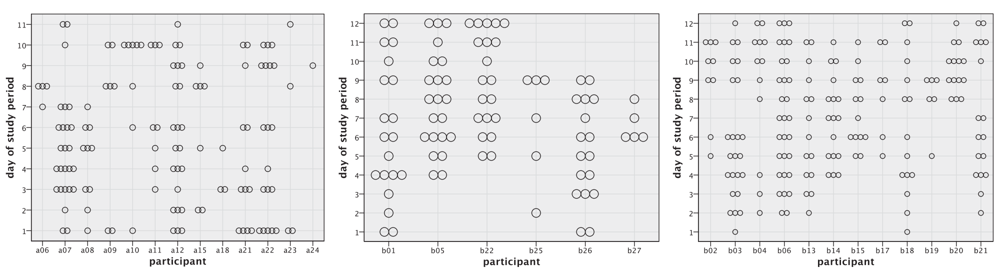
Between cultural profiles, a visual inspection to the distribution of daily reports for the 'null' and 'low' categories indicated a different distribution, therefore mean values were used for the tests. The results of the tests shown in Table 12(III) indicate that for the 'null' category the mean of days with no reports was statistically significantly higher in the autonomous-supportive organization than in the controlled oriented one, whereas 'low' category was statistically significantly lower in the autonomous than in the controlled oriented organization. A visual inspection to the distribution of daily reports in the 'mid' and 'high' indicated a similar distribution between cultural profiles, therefore the median was used for the tests. The results of the tests shown in Table 12(IV) indicates that the median of both categories in both cultures was not statistically significantly different; between thermal profiles, no statistically significant differences are observed (see Table 12V).

Table 12. Differences in categories of occupants' reporting behaviour (null, low, medium, and high) for cultural (A: autonomous; C: controlled) and thermal profiles (c: comfortable; w: warm).

(I) Median diff. of all reporting categories – within cultures	
$null_{A=7.0} > low_{A=3.0}$	$diff_A = 4.0$, P=.039
$null_{C=4.0} < low_{C=5.0}$	nss[a]
$null_{A=7.0,\ C=4.0} > mid_{A=1.0,\ C=1.5}$	$diff_A = 6.0$, $P = .006$; $diff_C = 2.0$, $P = .003$
$null_{C=7.0,\ C=4.0} > high_{A=0,\ C=0}$	$diff_A = 6.0$, $P = .003$; $diff_C = 3.5$, $P < .0001$;
$low_{A=3.0,\ C=5.0} > mid_{A=1.0,\ C=1.5}$	$diff_A = 2.0$, $P = .012$; $diff_C = 3.0$, $P < .0001$;
$low_{A=3.0,\ C=5.0} > high_{A=0,\ C=0}$	$diff_A = 2.0$, $P = .003$; $diff_C = 4.0$, $P < .0001$;
$mid_{C=1.5} > high_{C=0}$	$diff_C = 1.0$, $P = .004$
(II) Median diff. of all reporting categories – within thermal profiles	
$null_{c=6.0,\ w=4.0} > mid_{c=1.0,\ w=1.5}$	$diff_c = 6.0$, $P = .006$; $diff_w = 2.0$, $P = .003$
$null_{c=6.0,\ w=4.0} > high_{c=0,\ w=0}$	$diff_c = 6.0$, $P = .003$; $diff_w = 3.5$, $P < .0001$;
$null_{c=6.0} > low_{c=4.0}$	*nss*
$null_{w=4.0} = low_{w=4.0}$	*nss*
$low_{c=4.0,\ w=4.0} > mid_{c=1.0,\ w=1.5}$	$diff_c = 2.0$, $P = .012$; $diff_w = 3.0$, $P < .0001$;
$low_{c=4.0,\ w=4.0} > high_{c=0,\ w=0}$	$diff_c = 2.0$, $P = .003$; $diff_w = 4.0$, $P < .0001$;
$mid_{w=1.5} > high_{w=0}$	$diff_w = 1.0$, $P = .004$
(III) Mean diff. of null-low reporting categories – between cultures	
$null_A > null_C$	$U = 66.500$, $z = -2.034$, $P = .042$
($mr_A = 19.88$, $N_A = 13$) ($mr_C = 13.19$, $N_C = 18$)	
$low_A < low_C$	$U = 181.000$, $z = 2.595$, $P = .009$
($mr_A = 11.08$, $N_A = 13$) ($mr_C = 19.56$, $N_C = 18$)	
(IV) Med. diff. of mid-high reporting categories – between cultures	
$mid_{A=1.0} < mid_{C=1.5}$	*nss*
$high_{A=0} < high_{C=0}$	*nss*
(V) Mean diff. of all reporting categories – between thermal profiles	
$null_c > null_w$	*nss*
($mr_c = 17.71$, $N_c = 19$) ($mr_w = 13.29$, $N_w = 12$)	
$low_c < low_w$	*nss*
($mr_c = 14.45$, $N_c = 19$) ($mr_w = 18.46$, $N_w = 12$)	
$mid_c < mid_w$	*nss*
($mr_c = 14.40$, $N_c = 19$) ($mr_w = 18.38$, $N_w = 12$)	
$high_c > high_w$	*nss*
($mr_c = 16.55$, $N_c = 19$) ($mr_w = 15.12$, $N_w = 12$)	

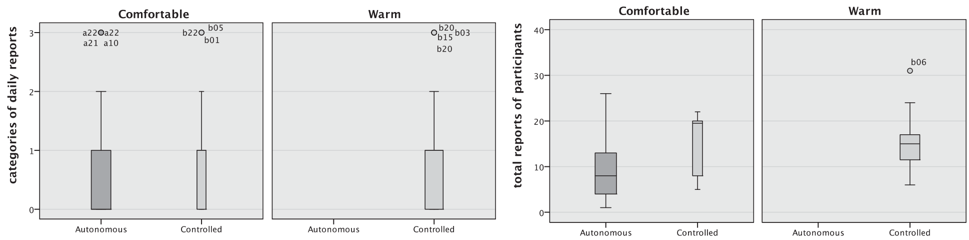
[a] *nss: not statistically significant.*

These different patterns could reflect aspects of working cultures that influence participation; the less density and clustered representations in Figure 9 (left) could be explained by the flexible and autonomous culture in building A, whereas a steady representation of the majority of reporters in Figure 9 (mid/right) could reflect the fixed and controlled



(a) auton-comf (b) controlled-comf (c) controlled-warm

Figure 9. 2-D dot plots of participants' daily frequency overtime: number of circles in a cell represent the number of reports from participant *x* in day *y* ('null' or no reporting is represented by an empty cell): (a) auton-comf, (b) controlled-comf and (c) controlled-warm.



(a) categories of daily reports

(b) total reports

Figure 10. Box plot describing the variance and central tendency of (left) categories of daily reports ($N_A = 156$, $N_C = 216$ reports); (right) total of reports ($N_A = 13$, $N_C = 18$ participants): (a) categories of daily reports and (b) total reports.

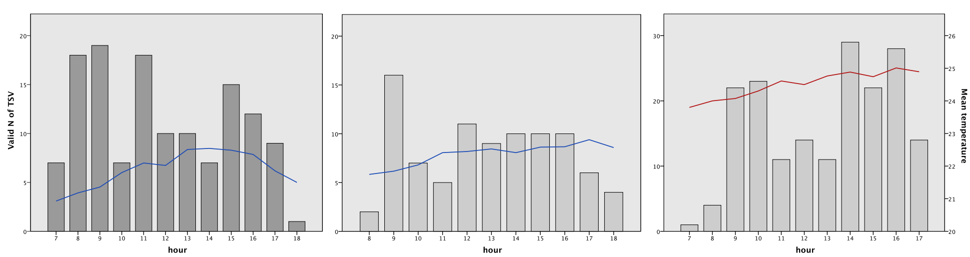
working culture in building B. In summary, the results of the non-parametric tests indicate that occupants of an autonomous-supportive organization (building A) had a more sporadic reporting behaviour both daily and overtime, than occupants of a controlled-oriente-dorganization (building B). This is confirmed by the description of variance and central tendency presented in Figure 10 (left), where thecontrolled oriented organization has a median of 1 whereas the autonomous-supportive one has a median of 0. Similarly, the description of total reports confirms this behaviour (Figure 10, right).

From the above analysis, Mann–Whitney *U*-tests between thermal profiles have shown no statistically significant differences were obtained among categories. To further confirm the weak relation between room thermal profiles and occupants' participation profiles, Figure 11 shows a dual *y*-axes plot that integrates number of reports (top) with the hourly mean indoor temperature. From visual inspection to Figure 11, it can be observed that on an hourly basis, temperature increases have no relation with changes in number of reports, on the contrary, a semi-fixed scheduling was predominantly observed.

3.4. Surveys

The response rate of the post-surveys was relatively high, 9 (69%) and 15 (79%) responses in building A and B respectively. Results are presented around two topics: experiences and suggestions for improvement related to the study design and materials used for self-reporting.

In general, the platform and study design supported a low burden and purposeful reporting activity for occupants across organization; participants experienced an easy



(a) Auton.-comfortable

(b) Contr.-comfortable

(c) Contr.-warm

Figure 11. Integration of temperature's profiles with room's participation profile: (a) Auton.-comfortable, (b) Contr.-comfortable and (c) Contr.-warm.

and quick way to report. Remarks and suggestions for improvement revolve around issues of personalization in reminders (e.g. protocol and content), reminders embedded in the context (e.g. app or sensors), pulled strategies to request reports from occupants (e.g. when nearby a sensor), options to input on other comfort related factors that affect their working experience (e.g. humidity, dust levels, luminosity), real-time feedback at location that is valuable overtime, opportunity to see an impact of their voting on facility managers' decision. Participants appreciated the flexibility to provide input. Participants of building B considered useful the email reminders, whereas in building A email reminders were perceived as having no impact on their frequency of reporting. The above points were identified as potential improvements to sustain participants' motivation, however, participants' active role in self-reporting related mostly to the perceived added value of the activity as a whole (e.g. clear contribution, clear benefit) and the specific parameters on which participants could report beyond thermal comfort.

4. Conclusion

This paper reports on the use of an innovative socio-technical measurement platform to investigate active collaboration of building's occupants in *in situ* daily reporting of comfort variables during working hours. Across cases it was observed that TSV was predominantly neutral, and neutrality and pleasantness votes were related. From a visual assessment of Figures 6 and 7, a positive relation is observed between TSV and indoor temperature, with nuances across the organizational profiles. It can be seen that the increase rate of TSV temperature is higher in the autonomous than in the controlled oriented organization, as well as the mean TSV. When excluding from analysis the comfortable group in the controlled oriented organization (their representation was relatively lower than the comfortable and warm group in the autonomous-supportive and controlled oriented organizations respectively), it was observed that occupants in comfortable rooms experienced higher discomfort with relatively similar changes in temperature than occupants' in the warm rooms.

Beyond summarizing the main outcomes, this paper seeks for understanding the impact of the reporting behaviour on the validity and reliability of the assessment. To counteract on the known issues related to the subjectivity and non-systematic collection of *in situ* data, this paper embeds a rigorous analysis of occupants' reporting behaviour in the assessment of comfort. For all participants, the reporting behaviour was on voluntary basis with the purpose to contribute to the wellbeing of their own working space. Reporting in itself was considered a purposeful group activity. In general, the distribution of daily reports was shaped by the suggestion to report three times a day, what resulted in a fairly constant distribution across weeks (regardless changes in temperature or different temperature profiles). Despite these generalities, relevant nuances across cases were observed which led to the definition of a reporting typology. The typology describes two types of reporting styles contemplating the reports' distribution across participants, across time and across temperature profiles.

4.1. Typology of reporting behaviour

Two reporting behaviours can be identified and described by the following three characteristics: *sample representation*, refering to the distribution of reports across participants/rooms (see Figure 9); *longitudinal representation*, defined as the distribution of reports across participants/time (see Figure 9); and *voting representation*, defined as the distribution of reports across the voting scale (see Figure 7). The sample and longitudinal representation of the reporting behaviour describe the completeness of the dataset (number of participants reporting at different times and days) and the voting representation impacts the granularity of the dataset (number of votes across the scale).

Autonomous reporting Occupants of building A working in an autonomous-supportive culture can be characterized as performing 'autonomous reporting'. This reporting is defined by the motivation to: *contribute* to the company's goal to increase comfort and decrease energy use; *learn and act* by using the feedback to increase their knowledge on the situation and explore alternatives; *make it meaningful* by looking for personal relevance to engage in activities involving equally personal and organizational strategies. This behaviour generates a dataset characterized by

- *an inconsistent and low sampling representation* as a small group of the active sample of participants contributed to the majority of reports (half of reports were reported by less than 25% of autonomous reporters);
- *a sporadic and decreasing longitudinal representation* as participants adopted a flexible reporting behaviour with a slight decreasing frequency at the end of the study;
- *a variability in the voting representation* as votes covered a large range of temperatures and were distributed widely across the TSV scale (e.g. the IQR in Table 9 indicates that half of the autonomous voting covers a wider range of temperature (1.6 °C) than the controlled profile).

Controlled reporting Occupants of building B working in a controlled oriented culture can be characterized as performing 'controlled reporting'. This reporting is defined by the motivation to: *comply* to the study instructions; *learn and share* by using the feedback and find the relevant information to inform the organization for further action; *make it systematic* by looking for stronger organizational strategies to assist them in providing accurate and relevant data. This behaviour generates a dataset characterized by

- *a consistent and high sampling representation*, as a large group of the total participants contributed to the majority of the reports (half of reports were reported by more than 40% of controlled reporters);
- *frequent and constant longitudinal representation* as participants adapted their work to the reporting activity, adjusting a fixed schedule and a consisting even increasing tendency of reporting;
- *a uniformity in the voting representation* as votes covered a small range of registered temperatures and are concentrated in a small subset of the total TSV scale (e.g. the IQR (in Table 9) shows that half of the controlled voting covers a narrower range of temperature (0.9 °C) than the autonomous profile).

The typology of reporting behaviour could be used to assess the reliability (completeness) and validity (granularity) of the dataset, and to consider contextual explanations of a quantified observed phenomenon. From the results of this study, it can be initially concluded that the autonomous reporting behaviour resulted in a dataset with a lower reliability but higher validity than in the controlled reporting behaviour.

5. Discussion and future work

The proposed distinction of autonomous and controlled types of participant reporting behaviours provides an integrated explanation of the collected data and has implications for further development of the *in situ* ICT measurement platform and design of future studies.

First, to explain the high sensitivity of the TSV reports from the comfortable groups in the autonomous-supportive organization, an analysis around commonly used aspects that are included in a typical assessment are investigated. Based on the study designed and observed results, most of these aspects are considered similar across cases: exposure to sunlight of the measurement tools (sensors and participants), weather season, indoor/outdoor daily working patterns and building characteristics (see Section 2.1), as well as daily indoor temperature fluctuations and subjective interpretation of the TSV scale (see Section 3.1 and Figure 8 respectively). With regards to subjective patterns (Bluyssen et al., 2011; Havenith, Holmer, & Parsons, 2002) (e.g. clothing, metabolic rate, mood, personality traits, interpretation of comfort scales) although relevant and potentially influencing factors, they are considered outside the scope of this analysis since embedding them requires an analysis at the individual level.

Using the proposed typology, working motivations could further explain the phenomenon. For example, the underlined motivations in autonomous reporting indicate participants' interest to learn from the information captured and act accordingly, which could influence participants' responsibility of consciously reporting and reflecting to small changes in temperature. Considering that participants' attitudes and behaviours of reporting varied, such variability should be represented in the outcome of the TSV analysis. This goes in line with the findings of Hauge et al. (2011) on the influence of social context and the attitudes and meanings that occupants associated to the building, on the building evaluation.

Second, to establish a meaningful and committed reporting behaviour, several implications are identified for future implementations of the BOCS platform in relation to the proposed typology:

- Implementation of contextualized triggers – refers to triggers based on contextual variables (e.g. under specific temperature, nearby a specific sensor, etc.). Although defined to support both autonomous and controlled cultures, smart triggers are expected to be more effective for the controlled than the autonomous organizations. This is based on the insight that controlled reporting works better if it is driven by reminders as reporters seek to provide more systematic outputs.
- Implementation of personalized triggers – refers to triggers based on personal variables (e.g. number of reports compared to others, weekly schedule of reminders, etc.). The personalization is also shaped by the means used to trigger (e.g. by email, SMS, phone notification, etc.). Investment in personalization is expected to be more effective in the autonomous-supportive than controlled-oriented organizations due to the need for high flexibility in the reporting style.
- Implementation of local feedback – refers to the display of indoor climate and comfort votes feedback at the area where they originate (e.g. a display in each sensor box). Although defined to support both approaches, local feedback is expected to be

more effective in the autonomous than in the controlled group. This expectation is based on the insight that participants with an autonomous reporting style are actively searching for information to act upon.

- Implementation of variety in subjective voting – refers to the balance of keeping a simple yet rich interface to report not only on neutrality by means of standard comfort scales but also on variables that relate to pleasantness. It is expected to impact both organisational cultures by increasing the meaningfulness of reporting.
- Implementation of 'virtuous circle' strategies – refers to the strategies implemented to connect reports with feedback and concrete actions (Menadue, Soebarto, & Williamson, 2013). A top-down strategy would be more effective for controlled reporting behaviour where it is expected that the system/organization provides responsive interventions; a bottom-up strategy would be more effective in autonomous reporting where it is expected to receive suggestions to activate personal/group initiatives. It is worth noting that a top-down approach implies high economic costs, whereas a bottom-up strategy requires social costs.

Finally, recommendations for the study design to address the main methodological pitfalls of each reporting style, are suggested. In general, participation strategies should adjust for controlled and autonomous reporting by considering differences in fixed versus flexible reporting protocols, authoritative versus suggestive styles of reminders and personal versus organizational means for reporting and giving feedback, respectively. Specifically, autonomous reporting would benefit from high numbers of reporters per area in order to improve the density of reports; while controlled reporting would benefit from high variety in reporting targets to improve fidelity.

This paper discussed the methodological accountability of embedding reporting behaviour analysis and contextual factors in the assessment of comfort. A preliminary reporting typology was developed based on a small-scale data collection in two buildings including 11 working days across 2 weeks of monitoring data and *in situ* self-reporting involving a total of 50 participants. Despite the small scale limitation, the presented analysis provides a detail and in-depth account of the contextual factors involved in self-reporting methodology. Future work should, on the one hand continues analysing reporting behaviour in commercial as well as residential buildings to further develop and extend the reporting typology. On the other hand, the presented preliminary outcomes provide foundation for further development of reporting interfaces for both controlled and autonomous reporting styles.

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