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ABSTRACT

According to the EC Action Plan for Energy Efficiency, a reduction of up to 30% in energy use within the office and commercial building sector can be achieved through occupant behavior change. Multiple studies support similar estimations for countries outside of the EU (e.g. Lopes et al. 2011). Depending on the building type, office occupants can perform various low energy actions to increase office comfort (e.g. Barlow & Fiala, 2007). However, sustained behavior change ensuring energy-efficiency may be difficult when not embedded and enforced in everyday office practices.

This paper describes an approach based on co-creation methods as a means to engage office occupants to make them conscious of the impact that their actions have on comfort and energy use by reflecting on results from measurements and observations. Methods to create awareness include co-designing of a monitoring platform, self-reporting mechanisms and feedback systems, enabled by modular hardware and an adaptable software platform. Through the co-design process supported by engineers and designers, occupants define ways of how sensor monitoring, self-reporting and feedback displays can be introduced into their office environments to stimulate and guide their energy-efficient and comfort-efficient actions in the context of everyday office practices.

The co-design approach is currently being deployed and evaluated in an ongoing study, which is being conducted in three large office buildings, each involving an experimental and a control group. Co-design workshops have demonstrated the value of involving office workers in exploring how best to involve stakeholders across various functions in the organizations. Office occupants were found to be particularly motivated towards improving comfort, which can act as a pathway to shaping energy behavior.

Energy meets comfort in social practices of office occupants

Counteracting the climate change caused by excessive greenhouse emissions is an urgent, global issue. Almost 50% of the global greenhouse gas emissions originate from the built environment, and office buildings constitute six to seven percent of the global building stock (Navigant, 2013). The most common approach to mitigate the negative impact that buildings have on the environment is to implement energy-efficient building technology, use renewable energy sources, and construct with sustainable building materials. However, building occupants may still use technologically efficient buildings in non-energy-efficient ways. In fact, improving the building's technological performance may have adverse effects on its occupant energy behavior. Occupants may exhibit rebound effects, whereby awareness of being in an energy efficient building, causes them to assume that saving energy is no longer needed, or lock-in effects such that old practices are carried on from less energy efficient building situations, preventing the optimal use of the new or upgraded buildings. Solutions that involve building automation may further reduce occupant's awareness and sense of responsibility for energy consumption levels (O'Brien & Gunay, 2014). Several studies also indicate that automated building features may reduce occupant's tolerance to factors causing discomfort (e.g. Brager et al. 2004) and future-oriented approaches call for "reconciliation of human and building intelligence"(Cole & Brown, 2009).

From the perspective of a building occupant, saving energy may contradict the need for thermal comfort and comfort in general. Facing everyday moments of perceived choices between saving energy, or supporting one's comfort, occupants are likely to compromise energy saving and choose comfort, which is directly linked to their productivity and well-being. Thermal comfort models such as predicted mean vote (PMV) enforce perception of polarity between comfort and energy saving, in such models people are viewed as passive receptors of the environment (Roelofsen, 2013). Such an approach implies that optimal indoor climate parameters can be universally defined for all building occupants. Consequently, sustaining such optimal parameters requires continuous use of energy, while in reality it does not cater to occupants with non-mean preferences. These occupants need to make additional effort, and use additional energy to meet their comfort preferences. Chappells & Shove (2005) propose an alternative way of looking at comfort as a 'highly negotiable socio-cultural construct', and observe comfort as 'an achievement, rather than an attribute'. This implies that 'comfortable' means an environment in which people can make themselves comfortable; i.e., an environment that offers sufficient possibilities or opportunities for adjustment and adaptation to achieve comfort (Chappells & Shove, 2005; Shove et al., 2007). The opportunity to achieve comfort is dependent upon how people interact with the 'material' or equipment afforded by their environment, their 'skills and 'meanings' or motivation to change. Opportunities to achieve comfort depend upon how people interact with their environments, modify their behaviors and practices and gradually adapt their expectations to match their surroundings.

The implication of viewing comfort as an achievement rather than as an attribute, implies office dwellers should be directly involved and supported in optimizing comfort. Furthermore, office workers can be engaged in optimizing comfort in relation to energy consumption, in particular for heating and cooling energy. Given the large variety of office buildings and activities as well as individual differences, a method is sought which can rapidly lead to customized solutions to help office dwellers achieve comfort while adopting energy efficient practices. The method involves co-creation sessions, the deployment of an user-adaptable platform for self-monitoring and self-reporting, along with climate sensors embedded in the work environment, and iterative user research.

Integrating user research, design exploration and solutions

The approach, methods and tools presented in this paper have been developed for the Building Occupancy Certification System (BOCS) project, which is part of the Building Technologies Accelerator (BTA) program of the European Climate Knowledge Innovation Community (C-KIC), being Europe's largest program focusing on climate change. The general goal of the BTA project is to develop market-ready solutions to reduce the CO_2 footprint of office buildings and in the long-run to certify office occupancy practices. In supporting a given building occupants change of practices, in relation to comfort and energy use, an in-depth understanding of current user routines around energy and comfort need to be gained.

Social practices are "broad cultural entities that shape individuals' perceptions, interpretations and actions within the world" (Hargreaves, 2011) which involve materials, skills and meanings. Social practices can largely vary across office buildings, or even within one building. Identifying concrete approaches towards shaping social practices is a creative process, which requires an in depth understanding of current social practices, as well as the opportunities for change, given the existing work organisation, social-cultural aspects, and the physical environment, including building technology. An additional complication here is that social practices related to comfort and energy may differ between times of the year, due to different weather and sunlight conditions.

The design of solutions aimed at modifying certain social practices relating to comfort and energy behavior in the office workplace can be time-consuming given steps including, surveying, designing, testing, and monitoring are required to help ensure the desired change occurs and new practices are adopted. In order to deal with this challenge an approach is presented here, where analysis of practices, identification of solutions and implementation are performed iteratively, such that they can mutually support each other, leading to the accelerated design and implementation of solutions.

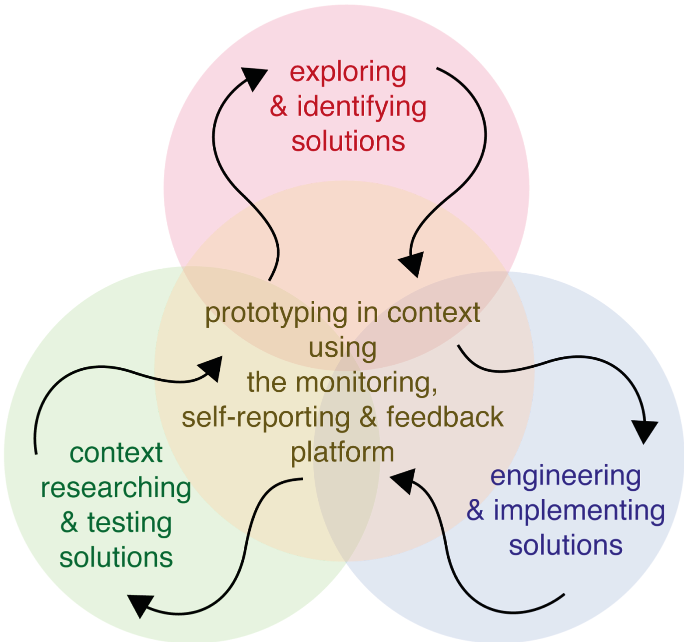

Figure 1. The approach here combines context research, solution identification and solution implementation in an iterative cycle, where the BOCS platform plays a central role as a research instrument and enabler of social practice transformation.

The BOCS approach depicted above is based on running co-creation workshops to gain rapid insights, a monitoring platform consisting of sensor and self-reporting nodes, optional feedback devices, online interfaces, and a back-end for collecting and processing gathered data. The platform combines aspects of a research instrument, namely a research platform for monitoring subjective and objective parameters of offices, a kit of parts for exploring solutions for supporting occupants in changing their practices, and the foundation of a system to be deployed on the long-term to support the target group in maintaining or improving energy and comfort related practices. With the BOCS platform user research and testing, generation of new solutions and their implementation are performed iteratively, integrating the three activities as shown in Figure 1 above. The monitoring, self-reporting and feedback platform are deployed in parallel. The platform can be seen as a continuously evolving prototype design in context (Coughlan et. al., 2007), driving change in the office context by permitting insights into the context, allowing identification of new opportunities, and allowing their implementation and validation.

Understanding comfort and energy in occupant practices

Lopes e.t al. (2011) provide an overview study which indicates that office occupants can perform certain actions to reduce energy consumption. For example, turning off the lights, closing windows and turning off the HVAC equipment at night and during weekends, or adjusting area temperature controls consciously. However, office workers may be resistant to adopting such changes, not only as individuals, but also at the group level.

In order to understand and counteract potential resistance to change in organizations, one needs to identify and understand social practices, in which the habitual actions of office occupants enforce each other which may have a negative effect on comfort and energy efficiency. By not only identifying specific actions, but also in understanding the social practice context in which actions take place, one can develop solutions for effective behaviour change. Such behaviour change can imply changes in current practices or the adoption of new routines.

The steps outlined in this paper towards changing comfort and energy related office workplace are: (1) identification of comfort-influencing and energy-use-impacting practices via observations and interviews, (2) analysis of the identified practices in relation to climate sensor monitoring, self-reporting of subjective factors by office occupants, and additional observations and interviews, (3) normalisation of the findings using a shared format for description and comparison of practices, and (4) identification of practices that can be improved, and (5) the evaluation of implemented changes to practices.

In step 1 above, a contextual questionnaire aimed at identifying key social practices and the subjective perception of comfort and energy in the workplace is administered. A timeline is filled in by participants, as shown in figure 2 below. The step includes encoding observations performed by a researcher in-situ and a post-observation interview format for verifying these observations.

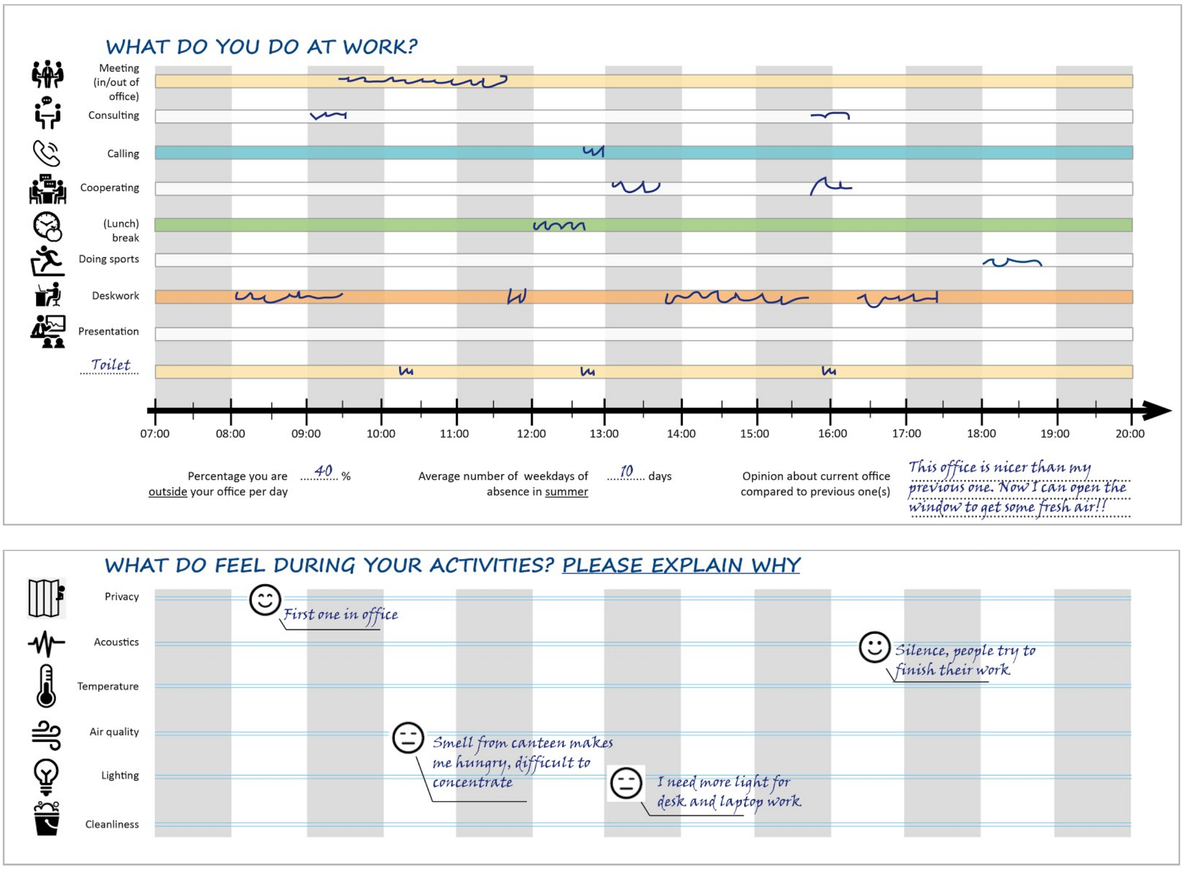

Figure 2. An example of a timeline filled in by occupants as part of a contextual questionnaire, as a means to help identify common social practices in the office and their relationship to comfort and energy use.

The evaluation of comfort and energy use related practices requires a more in-depth investigation than can be gathered by observations, interviews and questionnaires alone. Bazley (2015) through traditional means such as qualitative interviews and videos identified temporal and dynamic aspects of comfort. For example, comfort was found to vary depending upon the time of day and week day. To this extent, the in-situ self-reporting methods combined with sensor measurements in the office environment further expand the repertoire of current techniques for subjective comfort measurement in the workplace, including use of questionnaires, interviews and video analysis. In the study reported here, a combination of sensors measuring CO_2 concentration, humidity, sound levels, temperature, light intensity and movement were used. The combination of subjective and objective data contributes to capturing the influence that specific actions as a part of occupants' practices have on the office environment, and in turn when viewable affect participants' comfort and buildings' energy use (Lockton et al. 2013). To analyze findings from the objective and the subjective measures, a template was developed which includes the materials, meanings and skills involved in the practice (Kuijer, 2014).

Pilot Study

The above combination of context research methods and techniques were applied over three days, as part of a pilot study executed in three office buildings of a large international organisation. A total of 33 similar offices participated, out of which 15 were located in one building coded as building A, and two groups of 9 offices in other two buildings coded as buildings B and C. The offices selected on the basis of similar sunlight exposure. Each office had between one and three occupants. The three buildings had different characteristics. Building A was recently refurbished and had limited possibilities of controlling HVAC installations, but allowed opening of windows. Building B had older, manually controlled installations. Building C was the older building, where very limited climate controls were available and windows could not be opened.

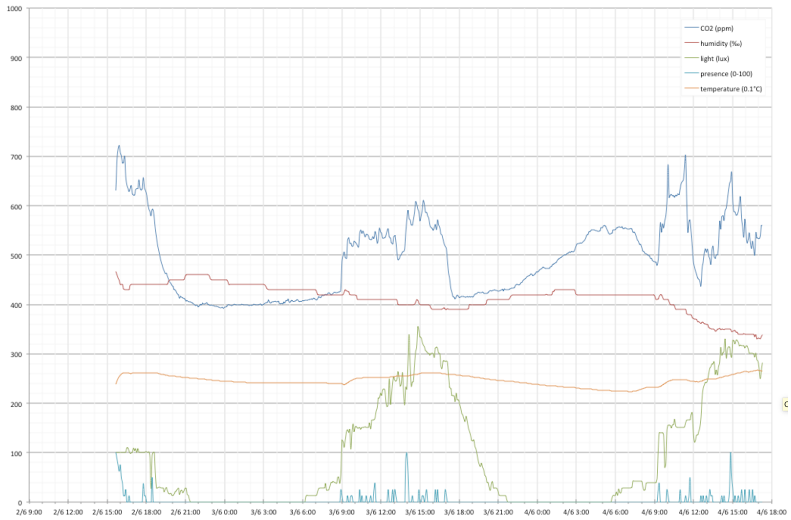

Figure 3. Objective data collected by sensor nodes placed in one of the studied offices.

The research in the pilot study led to identification of two social practices with highest potential for improvement, namely “focused desk work” and “informal office meetings”, which were further analysed. General correlations could be found between qualitative objective data and moments when these practices were occurring, but the patterns were not conclusive to identify the occurrence of the practices based on data only. Nonetheless the outcomes of the preliminary research enabled the inventory and analysis of key social practices occurring in the studied buildings.

Iterative co-designing

Identifying and analysing social practices in office environments and their relationship with occupant’s comfort and building’s energy consumption provides in-depth insights into the present situation, and allows to pinpoint specific aspects of these practices that offer opportunities for change. However, due to high intricacy of social office practices, their grounding in everyday habits, social relations and thinking patterns, a top-down enforced modification of a social practice is unattainable. As an alternative approach, co-creating a solution (Stappers & Mulders, 2011) with the occupants offers a possibility to take advantage of occupants being “experts in their own lives” in finding both practice improvement opportunities and concrete solutions to support them, as well as encouraging the involvement of participating users in the early adoption phase of the solutions.

The co-creation sessions were planned for time-efficiency, i.e., not to exceed 90 minutes. Before the start of co-creation sessions, practices identified and analyzed during context research were translated into sketchy storyboards, consisting of four to six pictures illustrating typical moments in the day of typical observed participants in a typical office. The style of the storyboards is deliberately fast and informal.

Figure 4. A sketchy storyboard is used to explain to participants the research findings and the correlation between observed practices and measured data.

The co-creation session consists of four phases. The first “reflection” phase takes 15 minutes and begins by a short explanation of the storyboard to participants. Printouts of anonymised data from monitored offices are used to show how different indoor climate parameters correspond to activities identified as part of the practice, how they influence comfort in that practice and what impact they have on energy consumption. Participants with assistance of researchers are then encouraged to label the storyboard with post-its, in order to indicate a) their own subjective feelings they associate with storyboard situations (yellow post-its), b) objectively measurable aspects of the environment which they can explicitly identify (red post-its), and c) opportunities they notice for improving comfort or reducing energy use. The second “opportunities” phase takes 45 minutes and is divided into two equal parts. In the first part participants discuss the opportunities identified and look for possible conflicts between energy use and comfort within these opportunities. In the second part participants are asked to identify possible positive and negative impacts that the opportunities for change may have on social relations in the office. During both parts occupants are requested to write down pronounced topics on post-its and organise them on corresponding flipchart pages. The third “concrete opportunities” phase takes 30 minutes. In the first part of this phase participants identify what objective and subjective data from their office can support them in achieving the identified practice change. They use stickers to signify those parameters on the storyboards. Following this step, they receive a template print-out, stickers and post-its to work in sub-groups to make their own storyboard of a future scenario of their own office practices incorporating earlier identified opportunities for change, and including sensors and feedback devices supporting this change. The session ends with short presentation of these future scenarios to each others. This final storyboard serves as an initial blueprint and “contract” with participants towards turning envisioned scenario into a reality.

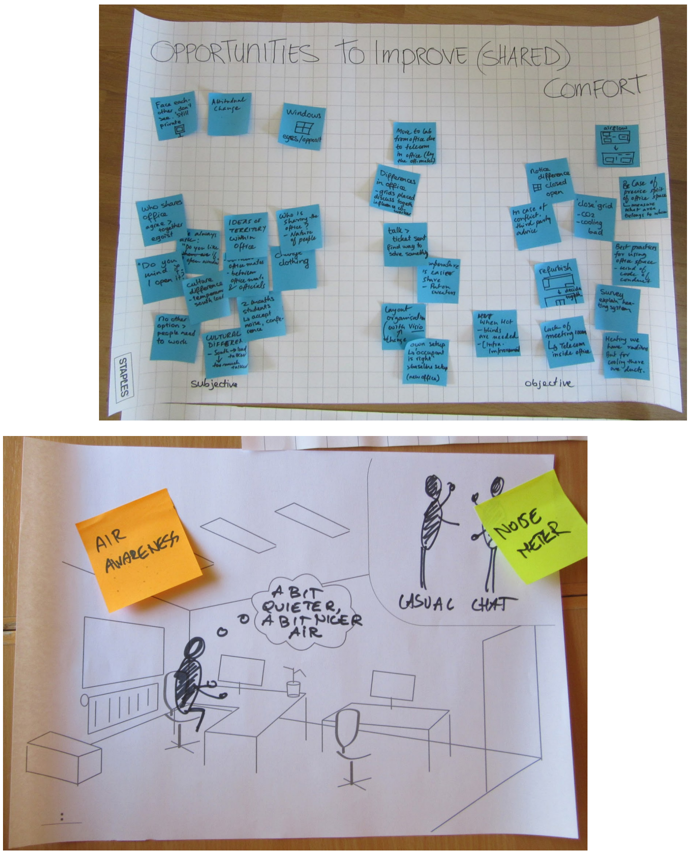

Figure 5. At the end of a co-creation session participants assisted by researchers summarise opportunities and post-its and sketch storyboards of a future scenario in which their comfort is improved and energy consumption reduced.

During the pilot study, one third of the selected offices were selected as “co-creators” and their occupants were invited to participate in the co-creation session. The remaining offices were split in two groups. In the control group participants were monitored, but did not participate in any activities stimulating practice change. The “testers” group was not invited to participate in the co-creation activities, but was later involved in testing the outcomes of the co-creation activities to allow isolating the impact of participating in co-creation on the engagement of occupants in using the developed solutions.

The co-creation sessions were performed over three days in three subgroups of participants from each of the three participating buildings. The attendance of invited participants was on average 40% of participants. The session required firm moderation due to the limited time for each of the steps. The duration of the session phases was very short, and proved difficult for the participants to focus on the given tasks. During the first session facility management personnel of the building actively participated, which appeared to stimulate participants to complain about the building facilities instead of constructively looking for opportunities. During the remaining sessions facility management personnel was instructed to withdraw from active discussion, yet sessions still required active moderations to encourage participants to be constructive instead of solely identifying problems. The co-creation sessions led to a number of unexpected findings. One example is sound disturbance, which was not explicitly mentioned during interviews, but in two out of three sessions became the main topic, and a driving idea behind the future scenario. Another example is the perceived air quality, which was identified as an important factor influencing multiple social situations and shaped practices. Solutions indicated in the future scenarios sketches included a system for providing subtle feedback between office occupants on noise levels, and a a meeting-timer influenced by air quality which could urge meeting participants to end the meeting when air quality decreases. In the case of individual offices, occupants could be triggered to open the window rather than run energy-intensive cooling systems for fresh air. The need to mark moments in time in which occupants would like to know a variety of indoor climate parameters was also expressed so as to reflect on the environmental quality of the work day. In the pilot iterations, time constraints were shown to be challenging, to keep on schedule firm moderation was required. Discussions between participants would frequently go off-topic and in all cases there was not enough time to synthesize the discussion in the final storyboard of the future. Nonetheless, the co-creation format provided a wide range of insights, and sessions hosts were able to synthesise the outcomes of the workshop into future scenarios during a follow-up session evaluation.

Implementing self-reporting and feedback solutions

The field pilot demonstrated the opportunity to use the BOCS measurement instruments to not only gain insights, but perhaps more importantly as a means to offer feedback, leading to behaviour change. The co-creation sessions resulted in a set of concrete future scenarios that occupants envisioned for themselves, featuring a selection of objective and subjective sensing devices, and feedback interfaces, which occupants were prepared to use as means to help identify new comfort and energy savings practices.

The BOCS platform was based on the Living Lab infrastructure developed in the SusLab project (www.suslab.eu). The changes made to the platform to support the pilot study were aimed at increasing the system's flexibility to fast adaptations regarding types of collected data, types of sensors used, types of self-reporting interfaces, and development of context specific on-screen and physical feedback interfaces.

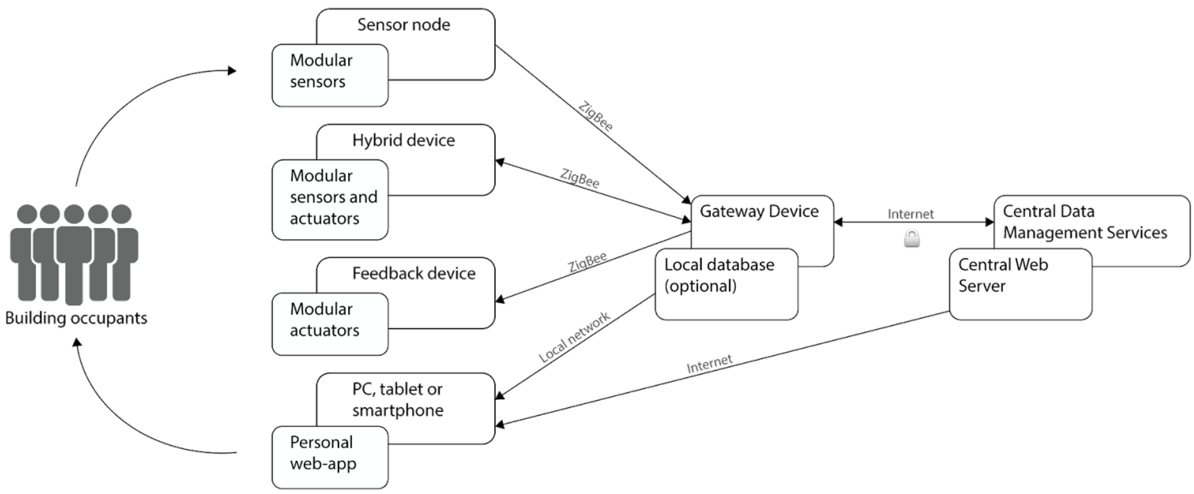

Figure 6. BOCS platform system architecture supports the rapid addition, modification and removal of system components based on local requirements.

The sensor and self-reporting device hardware was developed using modular electronic components. These components in combination with rapid-prototyped enclosures permit production of small batches of fully customized devices in the time frame of several days. A similar approach has been taken for the online feedback interface in which “monitors” have been developed as modular interface elements, which can be assembled into a custom dashboard for specific users based on local requirements..

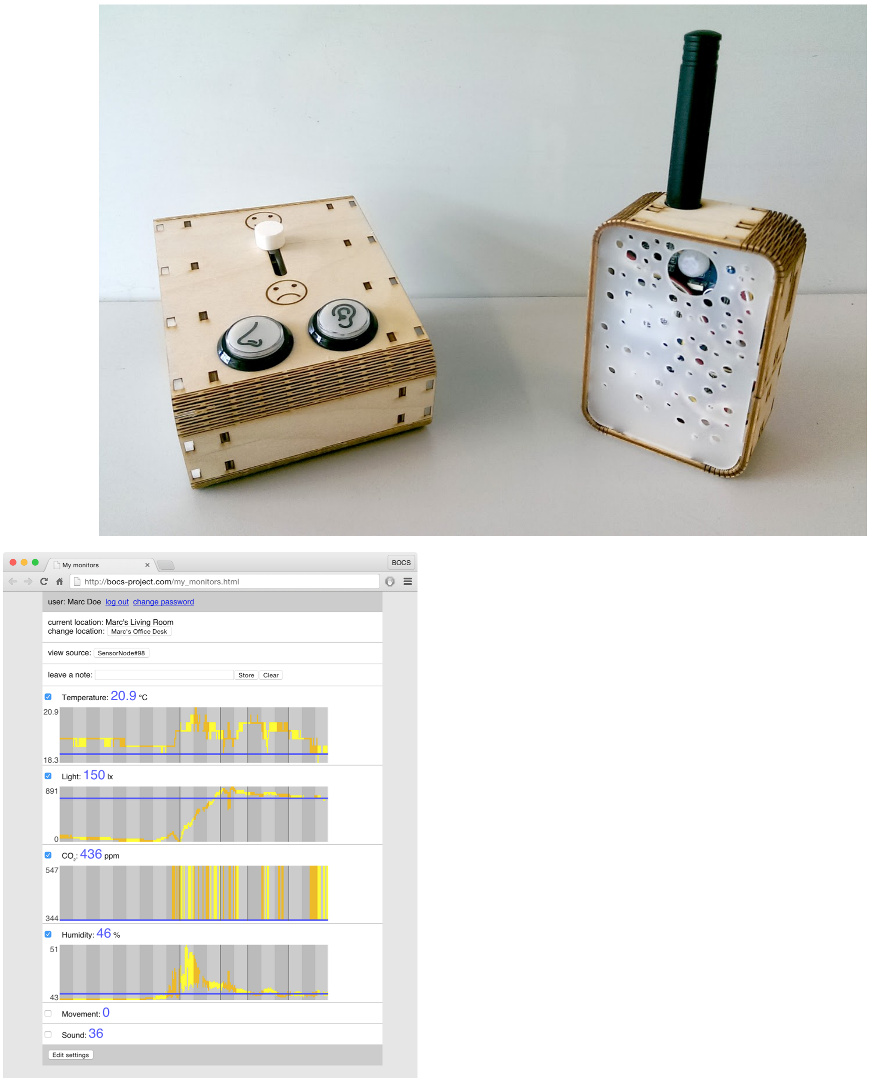

Figure 7. From left to right, the self-reporting controller with a flexible enclosures to accommodate different button and slider formats, a BOCS climate sensor node, and a personalised web-interface with the indoor climate feedback display pictured.

During the pilot study the co-creation sessions were followed by prototyping and development sprints sessions in which researchers, designers, and engineers jointly worked on translating the ideas for devices featured in the future office practice storyboards into working prototype solutions. This involved several development steps and the implementation of earlier unaccounted for features. The result of the development and prototyping sprint in the pilot study was a self reporting device, permitting occupants to press large buttons to indicate moments in which they were noticing that their comfort is impacted by bad air quality or noise. The device was additionally equipped with a slider, allowing the expression of occupant comfort level on a 5-step scale. The occupants could then correlate their subjective observations with objectively measured data via a web-app based feedback display. This web-app design has the flexibility to be adapted so as to provide self-reflection across a range of eco-comfort variables, and serves as a means for office workers to share data. Following the first research iteration of the pilot study, the prototyped devices, including subjective air and noise measurement were deployed among the participants in the experimental groups. The systems is currently being tested by pilot study office occupants as part of a second design iteration (as indicated in Figure 1).

Conclusions

The approach presented in this paper towards improving comfort while reducing energy consumption in the office place, seeks to demonstrate novel ways to innovate in the area of behaviour change involving complex social practices. Based on an iterative process, which can be considered as a holistic method, user research is combined with the development of design approaches that address behaviour change. Proposed solutions can be rapidly prototyped and evaluated. The first pilot study demonstrated that the BOCS approach can provide valuable insights towards identifying opportunities for office occupants to self-reflect on practices relating to comfort and energy use.

Dealing with social practices has shown to be a highly complex challenge. Surveys including easy to fill and analyse timelines, fast interview formats and robust objective data collection mechanisms have been implemented to accelerate the research on social practices in context. As a next step to improve the analysis and synthesis of findings, a social practice template is being developed to help identify relations between the skills, meanings and materials of practices (Shove, 2007).

The co-creation procedure was constrained due to limited time of participants' availability. Extended time availability of participants in future studies is thus unlikely, therefore solutions need to be found to further improve the outcomes of the procedure within the given time frames, and to possibly engage participants in co-creation activities informally outside of dedicated co-creation session during work time.

The implementation of co-created solutions has also proven to be a substantial challenge, as outcomes of co-creation cannot be fully predicted and the need for custom developments appears unavoidable. A possibility to further accelerate the deployment of co-designed solutions could be achieved through further development of the BOCS platform into a kit of parts that ultimately office occupants or building managers themselves could assemble into working solutions to gain insights and consider new practices, without the need for dedicated product engineers and developers.

Despite the above shortcomings, the first iteration of the approach was shown to deliver promising results. The question as to whether the approach can lead to changing social practices in a given context will be further examined during the second iteration of the pilot study. Perhaps the largest gain to date has been the development of the in-situ methods and tools.

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