SSO User Insight Toolbox for employees' health, well-being and productivity

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Users have significant impacts on building energy consumption and can interact with indoor environments. Identifying user needs, behaviour, and preference is crucial for the design of both new and the renovation of existing buildings. Offices are important since people spend on average one-third of their life at work. It also accounted for a larger share of the energy use and the floor area of non-residential buildings in Europe. Moreover, more ambitious regulations and the increasing popularity of voluntary building certification schemes require the construction of more energy-efficient buildings, but in reality, a 'performance gap' is often observed. Therefore, deep insights in user perceptions and experiences can provide the knowledge basis for developing a new generation of office buildings that provide a healthier and more productive indoor environment guided by a user-centric approach. In this article, we will introduce the web-based application of the Questionnaire and Diary Apps and a Virtual Reality (VR) design tool developed to support the interactive co-creation session with users and designers.

Buildings are responsible for 40% of energy consumption and 36% of energy-related CO_2 emission in the EU. In the European building stock, offices have a large share of 26% of the total energy use and 23% of the total floor area of non-residential buildings [BPIE, 2011]. Aiming for the 2030 climate and energy framework, office buildings play a key role with the targets of cutting greenhouse gas emission and improving energy efficiency in the building sector. The office environment is also important to the employees and society as a whole. We spend 80-90% of our lifetime in buildings, and office dependent working results in 90000 hours on average. Providing an agreeable indoor environment plays a key role in the building energy consump-

tion and is a vital part of human well-being existing in buildings [Bluyssen et al., 2011; Jin and Wallbaum, 2018]. Moreover, in line with the UN Sustainable Development Goals 3 "Good health and well-being" and Goal 8 "Decent work and economic growth", a sustainable indoor environment needs to be understood further to improve user comfort, health, and work performance. Even if we have standardized information for design and operation of desirable indoor climate, a "performance gap" is often observed between designed, measured and perceived indoor environmental quality (IEQ) as well as designed and real energy consumption in buildings [Altomonte et al., 2019]. Despite the knowledge existing within architecture, mechanical and civil engineering, facility management etc. to construct high-performance buildings, the results not always match with our expectations, e.g. that low energy building or green buildings are not so livable, and the smart buildings cannot control the indoor climate for occupants' real needs. One of the main reasons is that we still have a very blurry and fragmented knowledge of the different user behaviours in real buildings [Hong et al., 2017]. Users can have significant impacts on building energy consumption as they interact with the indoor environment in many ways. To achieve a higher building performance concerning both the energy perspective and indoor climate, we have to consider the user demands more comprehensively. Therefore, deep insights in user experiences can provide the knowledge basis for developing a new generation of office buildings that provide a healthier and more productive indoor environment guided by a user-centric approach. Consequently, user insight tools gain importance and several of them have been developed around the world. The paper will introduce two innovative tools that have been developed, validated and customized in different climate zones in Europe within the smart and sustainable offices (SSO) project funded by the EIT Climate-KIC.

The approach of "SSO"

The SSO approach is holistic a mixed-method approach of qualitative and quantitative measures, gathered in a so-called SSO User Insight Toolbox. See **Figure 1**. It combines comprehensive Apps of a web-based questionnaire, a web-based diary study, a user observation tool, deep and focused group interviews as well as IEQ physical measurements [Cobaleda Cordero, et al., 2018]. The SSO User Insight Toolbox covers a broad scope of users' health-related factors and captures their current

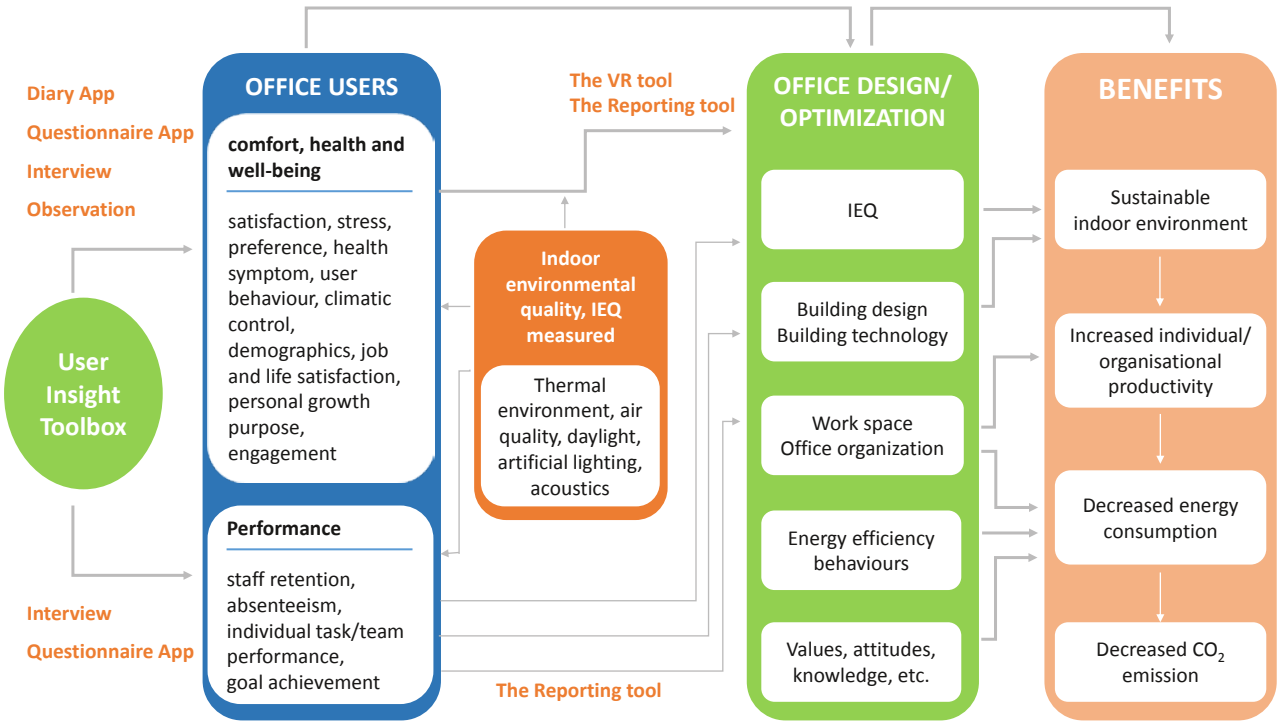

Figure 1. The approach of "SSO": A mixed-method approach of qualitative and quantitative measures.

and general well-being and their productivity. It aims to pioneer a diagnosis and strategy implementation for a new generation of user-oriented, lower carbon footprint, and resilient building design solutions to provide empirical evidence for future offices. One main focus is put on user experiences regarding the indoor environment, individual control and energy-related behaviour, such as thermal environment, air quality, lighting and daylight, and acoustics. Different web-based tools are used to collect the qualitative data from the user and building, and IEQ measurements collect the quantified data from the physical environment. Furthermore, the Reporting tool and the VR tool integrate both qualified and quantified results and provide recommendations for new office design or optimization.

Results

The Web-based SSO Questionnaire App is the insight tool to gain a holistic picture of the user's general experience in the office environment. The login interface is shown in **Figure 2**. This includes among others indoor climate, space design as well as the social work environment. Users' responses are collected on themes like e.g. of satisfaction, stress and preference. Furthermore, energy-related behaviour, perceived health, and self-reported work performance is also gathered. Individual context-factors and the character of work can also be observed with the tool. Finally, the insights in employees' general experience are gained alongside with additional insight in topics like mood, job- and life satisfaction.

The Web-based SSO Diary App is an innovative tool to track the daily changes of users' behaviour, perceived comfort, perceived health as well as occupancy and space use. The diary insight tool is used to identify the current experience, work pattern and user behaviour, more accurately related to the perceived and measured indoor environments. Furthermore, it can diagnose the factors of the stress and complaint from multi-perspectives such as physical indoor environment and job satisfaction. See **Figure 2**.

The Observation and focused group Interview are one-step of gaining in-depth user insights based on the web-based SSO Apps. An initial observation for each office is required to collect data regarding the physical environment. In the semi-structured interview, additional information is collected regarding the identified factors from the Questionnaire and Diary App studies and the observations.

The Reporting tool is adapted for the practitioners and users to help the building stakeholders including the planners (architects, designer, building engineers) to fully integrate the SSO insights into their own re-design processes. Therefore, a translation of these insights into a building information modelling (BIM) tool for architects/developers is vital for successful further entry of sustainable office design. The reporting tool shows the insight results at different levels, including the first level of fact and figure of user satisfaction, comfort, health and performance, the second level of diagnosis of IEQ

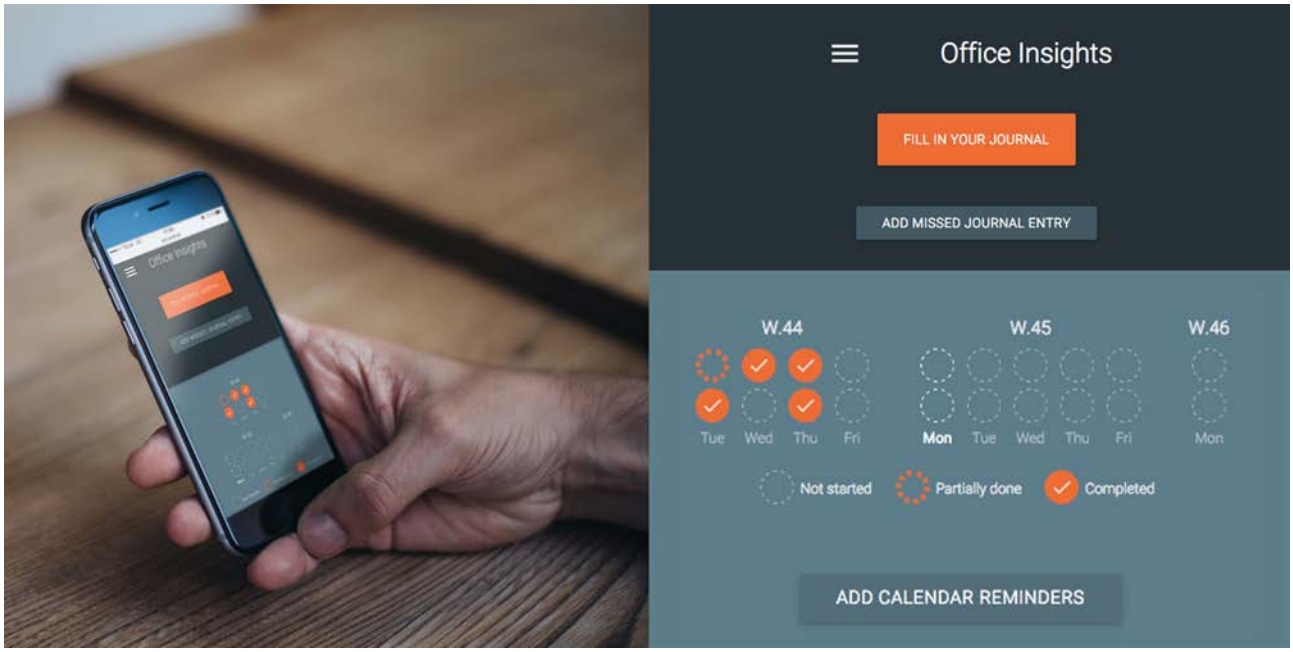

Figure 2. Web-based SSO User Insight Toolbox of Questionnaire and Diary Apps.

with perceived and measured results, and user behavioural and work pattern, and the third level consisting of recommendations for the (re-)building design of an innovative office environment. **Figure 3** shows the reported result of perceived stress in the indoor environment.

The Virtual Reality (VR) design tool is newly developed and based on the above described SSO User Insight Toolbox and is expected to further support interactive co-creation sessions with users and planners by creating a virtual office space based on the inside gained through the SSO mixed-method approach.

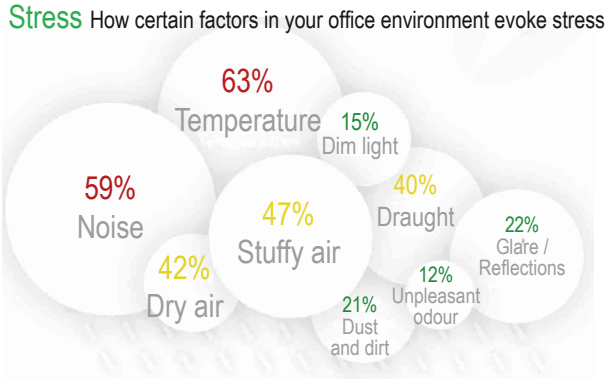

Figure 3. Illustration of the perceived stress for indoor environment reported by the Reporting Tool.

With the help of a created Virtual Reality, the occupants are enabled to make informed decisions and test and rate indoor environment according to their preferences.

Case example of User Insight Apps

A building has been extensively renovated in 2017 and was certified as *Miljöbyggnad* (the Swedish Environmental Building Certification) Silver, specifically addressing low energy consumption, comfortable indoor environment and creative workspaces. Energy-efficient features include sunshine shading, energy-efficient window, low U-value wall and mechanical VAV system. To examine the real performance of the building after the renovation, the SSO User Insight Apps were used to collect occupant responses of general experience indoors and also on a daily basis, for example filling in the Diary App in the morning and in afternoon during all workdays during the study period. **Figure 4** shows the user interface from the Questionnaire App for office indoor environment satisfaction of air quality, relative humidity and temperature. The distribution result of the responses on different perceived scale is also visualized in real-time from the SSO User Insight App's administrative side.

Figure 4. Illustration of user interface for voting office environment satisfaction on the Questionnaire App.

Case example of the VR tool

In the SSO approach, user feedback is key for each stage of the design process. During the co-creation sessions, employees will be wearing VR goggles while experiencing a fully immersive virtual environment. With a small hand controller, they can browse through each room in a first-person view. They are able to navigate through any selection or sequence of rooms, teleport, and even walk in the room virtually. The following case example shows the influence of daylight on users in the virtual office environment. By changing the location of the office and varying sky conditions and view directions, subjective perceptual ratings of daylight are collected and the satisfaction levels can be compared among different daylight conditions in different rooms. **Figure 5** shows the VR design result from daylight.

Photo by Adrian Dewerdt on Unsplash

Discussion

Comparing to the existing post-occupancy evaluation methods, the SSO approach can in-depth observe user experience, preference and behaviour in the building by using the web-based Apps and implementing the surveys with different time resolution and location information. For example, the App can track users' experience for the indoor environment in different time-slot and different rooms during the day which gives the opportunity to identify the patterns of comfort, preference, behaviour and occupancy. Furthermore, an innovative added value is provided by deep insight studies that complement each level, building the scientific ground for an advanced and demand-oriented building design.

The SSO User Insight Apps and the VR tool provide an efficient platform to collect user feedback while using the buildings. This is of great value to various building stakeholders including the end-users and enables easy communication and interaction, based on validated findings. One of the challenges to achieving a user-centric building design is an efficient communication among project developer, designer, engineer, and building owner since we still lack a standardized way of sharing this type of information. Thus, the tools developed from the SSO project will be of help to integrate the needs from various stakeholders, and in particular emphasize user needs. In parallel, the tools deliver valuable occupant related assumptions for the building designer/architect to be able to better achieve a user-centric and sustainable design.

The mixed-method approach of the SSO User Insight Toolbox has the potential to be adapted to other types of commercial buildings beyond offices that contribute largely to the CO_2 eq contributions as e.g. hospitals where energy savings of up to 40% are estimated. To combine evidence on human factors from patients and staff with building service technologies, interior design and workflow optimization, can also in this area lay the ground for a new smart generation of low carbon hospitals unique insight for the adaptation of the SSO-method to the healthcare sector.

VR realisation: Tengbom

Figure 5. Illustration of user experience on daylight in the virtual office room by the VR design tool.

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Conclusion

The SSO approach and the SSO User Insight Toolbox provide in-depth information on occupant experiences indoors, and the way how users tend to use buildings. Therefore, office workers' comfort, health, well-being and productivity can be holistically addressed. Furthermore, the performance of indoor environmental quality can be evaluated by both qualified and quantified data collection methods which provide more empirical data to create a healthier and more productive indoor environment guided by a user-centric approach. It also enhances efficient communications among various building stakeholders and the interactions between the building and its users to achieve a productive office environment. With the reporting tool and the VR tool, the information collected by the web-based User Insight Apps from the user and building can be further transferred to BIM for future digitalization in the building design process. The tools are developed to be adapted to the standard industry practice in the future. ■

Acknowledgement

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