H2020 MOBISTYLE project's showcase of the final results

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Especially in the times of pandemics, it is important that different building occupants are aware of the invisible correlation between indoor environmental quality (IEQ), personal health, human – building interaction and energy efficiency as through such established awareness, we can nudge new behaviours that can lead to a better well-being as more energy efficient buildings.

Keywords: Energy use, indoor environment, health, behaviour change, awareness campaign, people-centred approach.

This paper presents the final results of an interdisciplinary European H2020 project MOBISTYLE (MOtivating end-users Behavioural change by combined ICT based modular Information on energy use, indoor environment, health and lifestyle https://www.mobistyle-project.eu/en/mobistyle/Pages/default.aspx), designed to raise user awareness on importance of the correlation between indoor environmental quality, personal health, well-being and buildings energy efficiency. Based on the 5 different demonstration cases covering different EU geographical areas, different building typologies (social housing, private homes, hotel, office, public university buildings) and different building user types, MOBISTYLE concluded that rationally modifying indoor environment can enhance people's lives as also helps the environment.

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The MOBISTYLE approach

The aim of the 42-months long H2020 MOBISTYLE project (1st of Oct 2016 – 30th of Jun 2020) was to show that improving buildings and building technologies is not enough. In order to achieve ambitious goals of EU on energy savings in buildings, a different approach is needed where users of the buildings are equally important part of the building ecosystem as building technologies and building components characteristics. Therefore, the emphasis should be furthermore on educating users on how to use their buildings and how to increase their awareness by combined information on their energy usage, generated IEQ, health and lifestyle.

The MOBISTYLE approach is innovative in terms of providing mixed method research approach – complementation of quantitative and qualitative research. Such method provides a more complete and comprehensive understanding of the problem than using either quantitative or qualitative approaches alone. It provides an approach for developing more context specific instruments where the quantitative data (objective measurements through building's sensors) are supported with qualitative data (in depth analysis of occupants' behaviour through anthropological inquiries).

MOBISTYLE publications in two previous editions of REHVA Journals (Dec 2018 [1] and Oct 2019 [2]) introduced in the detail the MOBISTYLE objectives, the developed people-centred approach, behavioural action plans developed for the different demonstration sites as also technical details of the different developed MOBISTYLE ICT tools.

MOBISTYLE Demonstration

To summarize, the monitoring of demonstration buildings in MOBISTYLE covered the following real-life environments:

1. A campus of university buildings, more specifically, four faculty buildings – Faculty for Eco-nomics (EF), Faculty for Arts (FF), Faculty of Computer Science and Informatics (FRI), and Faculty for Chemistry (FKKT) in Slovenia;
2. A hotel environment in Italy;
3. A complex of residential buildings in Denmark);
4. A housing district connected to an electricity grid in Poland;
5. Two open plan office buildings in the Netherlands.

To satisfy the building occupants and users' needs at the different demonstration sites, the following solutions were developed:

- The Dashboard as a tool for buildings energy and IEQ monitoring, with a suggestions system to guide users toward a more efficient behaviour. It had been tailored for the two identified user groups in non-residential buildings: building occupants (employees – using mobile app version) as managers of the buildings (experts – using PC version). It has been tested for the Slovenian and Italian demonstration case.
- The Game as a gamified app for behavioural change on efficient energy use and for awareness creation on the associated health benefits for residential cases. It has been tested for the Danish and Polish demonstration case.
- The Office App as a dashboard for office spaces in order to stimulate the dynamic indoor conditions acceptance and had been tested for the Dutch case.
- The Expert Tool allowed building managers (demonstration case holders) harmonized management of different data types as also offered easy to visualize features. The experts were able to filter the information they need, calculate pre-defined KPIs as also set up their own KPIs.

Four business and exploitation plans were developed to support the developed solutions.

Demonstration cases results

Slovenian demonstration case:

- Beside MOBISTYLE dashboard application, extensive building tailored awareness campaigns based on the people centred approach were organized at the university building in Ljubljana Slovenia, that included in app information and notifications based on measurements, frames on relevant locations in the building, regular massages on public screens and air quality information via non-intrusive LED changing colour in offices.
- Quantitative data, acquired with sensors, helped to identify behaviour patterns for each room individually and for the building as a whole. Slovenian case results showed example of "attitudinal fallacy", where people either intentionally misrepresent their behaviour to make them look like they are adhering to the desired behaviour or their actions are simply too subconscious to report them accurately.
- Cooling usage was decreased even when the cooling degree days (the need for cooling) increased in all buildings (one faculty building for 13% and other

for 25% when comparing baseline and monitoring period when interventions took place).
- Heat use for heating was decreased in all buildings (gas consumption of FRI FKKT complex was reduced for 7%, district heat on EF for 12,4% and FF 9,1%) while heating degree days were decreased only for 5%.
- Personal elevators use was decreased in all cases (FKKT large –7,4%, FKKT small –13,2%, X –10,1%, FRI –14,6%. The 2 measured on EF: –32,6 and –4,3%).
- After the campaigns, the perception evaluation was done where people were confident that they understood how their actions affect the energy usage.

Italian demonstration case:
- Beside MOBISTYLE dashboard application, extensive awareness campaigns based on the people centred approach were organized especially for the hotel staff.
- MOBISTYLE stickers stressing on positive impacts on health of proper ventilation were successful. Stickers had a bigger impact than ICT-tools because they were easily visible without necessity to open an app (e.g. lower electricity consumption, lower CO_2). Staff members stated that the scars interest for ICT-tools was mainly due the lack of their integration with other services.

Danish demonstration case:
- Danish demonstration case addressed the social housing residents in Aalborg. The MOBISTYLE Game was developed to combine information regarding IEQ and energy.
- The ICT tool application (Game) led to improved IEQ in many apartments but had no impact on energy use. Occupants felt more informed and became aware of the impact of their practices. In Danish case, the low saving could be due to the fact that MOBISTYLE demonstration covered already renovated NZEB apartments, where the actual saving after renovation was higher than expected. The energy use for heating was therefore much lower than most occupants were used to from previous apartments and from before renovation, so they already experience much lower energy cost, which may be an important part of the reason
- The ICT system had limitations leading to loss of interest on a longer run. It had been noted that the main improvement would be achieved through a reduction of data flow latency, in order to allow the user to receive immediate feedback from their actions, and in ensuring a consistent and stable data flow from installed sensors (avoiding data loss).

Polish demonstration case:
- Polish demonstration case was aiming to achieve the behaviour change of the home occupants in Wroclaw, clients of Polish energy provider through an application of MOBISTYLE Game.
- Due to the boundary conditions of the project (innovation action) with limited resources, the project impact was not fully utilized due to limited number of data correlations leading to limited information provision.
- Most actions were related to improving IEQ (humidity and air temperature). Most building occupants remained within the 'healthy' boundaries of the different parameters. The game was treated more as an innovative gadget and not a system that actually could generate real changes in the use of particular devices and utility media consumption control. It seems that healthy home and gamification elements were the way to motivate people to become aware of the influence of their daily actions at home on the aspect of IEQ, however, these did not necessary lead to energy savings. To keep the interest on a long run, it seems the economic benefits should be made visible even if these benefits are small.
- Further Game development would be needed, having the ability to remotely control smart home devices, to compete with other smart home solutions available on the market.

Dutch demonstration case:
- Dutch case provided three studies to test whether dynamic indoor temperatures (compared to static) are acceptable. The hypothesis was that the dynamic temperatures can lead not only to improved metabolic and cardiac health but also lead to user's acceptance and comfort (see further research from the group of Professor Wouter van Marken Lichtenbelt from Maastricht University [3]).
- People found dynamic temperature profiles comfortable and the comfort levels were not significantly different from those of the stable temperatures. Despite the change in thermal sensation from slightly cool to slightly warm, the thermal comfort stayed within the limits of just comfortable and comfortable. The experiments for this case showed that dynamic conditions (moderate temperature drifts) do not lead to perceived thermal discomfort. The study indicated that metabolic healthy can be affected positively by dynamic indoor temperature

compared to fixed scenario without compromising thermal comfort.
- This is an important finding because it means that there is in fact no reason for stable control of the indoor climate. It was simulated that such dynamic campaigns can lead to average 21% energy saving compared to static conditions.
- MOBISTYLE Office App was developed for the Brightlands office building in the Netherlands to further increase occupant's acceptance of dynamic conditions satisfaction. The app also took into account occupants' satisfaction with IEQ through a simple feedback loop (voting feature).
- 85% of the office employees found the tool appealing where it educated the colleagues as office guests about the indoor conditions in the different meeting rooms as also provided feedback about potential benefits of the dynamic conditions. The experiments with wearables were part of this study.

MOBISTYLE Limitations

It is important to keep in mind that results have some limitations:

Statistical representativeness: In MOBISTYLE the sample size was relatively small, which is typical for ethnographic research methods, where small samples are examined in detail to understand behaviour of actual people, not generic target groups. The MOBISTYLE approach is innovative in terms of providing mixed method approach – complementation of quantitative and qualitative research. Such method provides a more complete and comprehensive understanding of the problem than using either quantitative or qualitative approaches alone. It provides an approach for developing more context specific instruments where the quantitative data (objective measurements through building's sensors) are supported with qualitative data (in depth analysis of occupants' behaviour through etnographic inquiries).

Large enough sample size would be crucial for obtaining statistically significant results, however, due to the project resources restrictions a large set-up of such detailed anthropological investigations was not possible. Furthermore, also limitations in the building sensoring capacity were identified and therefore only the most important indoor environment and energy parameters could be measured.

Uncertain variables: Our daily behaviour is complex, interrelated and therefore it is difficult to isolate single parameters influencing our behaviour especially on the long run. Studying 'soft factors' (also human factors) can therefore be more challenging than acknowledging the technological 'hard factors'. However, there lies a common understanding that without taking into account both, 'soft' as 'hard' factors, real energy efficiency cannot be met (in practice observed as performance gap). Also, effective occupancy was unknown for most of the cases due to the limitations in the building sensoring capacity.

Technical sensoring limitation: Several cases had missing data due to the problems with data acquisition, stability of data and capability of the system. The MOBISTYLE ICT system depended on several demonstration case related sub systems. Within the MOBISTYLE ICT system, data was acquired from the different sensoring devices (existing, new cost-efficient) with the different communication protocols and data exchange requirements therefore interoperability between the different systems was an issue. Clearly, the complexity of the different demonstration cases data gathering was underestimated. The EE-07-2016-2017 encouraged the use of low-cost sensors where such sensors sometimes had a poor quality, leading to poor data flow stability.

Rapid ICT developments: Actual MOBISTYLE solutions deployment and demonstration was realized more than three years after the submission of the proposed project's work programme. With the fast developments in the ICT area in the recent years, there are many new solutions entering the market that could be more suitable for MOBISTYLE purposes.

MOBISTYLE Main lessons learnt and final conclusions

MOBISTYLE project addressed different building typologies and different building user types. The project proved that it is not enough to only look at the raw sensorized building data (big data) where this data is needed to be correlated with the deeper insights into a case specific context and understanding of people's behaviour (thick data). This requires an interdisciplinary approach with wider understanding of the complexity and dependencies between people's behaviour, indoor environment – health, energy nexus.

Building use should be improved in order to ensure healthy, productive and comfortable living environments while using only necessary amount of energy. These aspects (introduced through innovative KPIs)

should be clearly visible to people, so they feel connected to their indoor environment and also to make them feel safe and relaxed, instead of overburdened with additional cognitive load; information and suggestions. Therefore, direct, dynamic, contextual and comprehensible feedback on energy consumption, indoor environmental quality (IEQ) and related health implications should be provided to people in a meaningful way in long term campaigns, since it assures constant improvements and changes of mindset on a longer run.

However, in this research project the monitoring results are based on a small sample and therefore are not sufficient for any statistical significance yet to come to validated quantitative recommendations. The monitoring results show that further investigation and especially large-scale monitoring campaigns, in combination with campaigns targeting behaviour, in different EU countries, would be useful, meaningful and necessary.

From data analysis, interpretation and personal communication, some relevant lessons can still be drawn about the effectiveness of MOBISTYLE-like behaviour campaigns:

- Energy efficient behaviour campaigns should not be seen as stand-alone solutions but should be part of the **community building** or **building facility management**. Various site specific (established) communication channels should be exploited for campaigns. Location associated **micro cultural specifics** need to be taken in to account when designing campaigns.
- **Cost-effective** and **simple multi-channel campaigns** can be very effective where information has to be **contextualized** and **long lasting** without bringing additional cognitive load. Furthermore, it is important to **target decision makers** as people listen to well respected people they trust within their communities.
- **Accessible, minimalistic solutions** and **low budget measures** (e.g. stickers, LED lighting, temperature training campaign) can have more immediate impact than complex systems (i.e. ICT-tools), which require the users to be fully willing to start using them and needs to devote more time and cognitive capacity to them.
- **Reliable technology** must be a priority. If the technology has a bug, it is valuable to "humanize" or "anthropomorphize" it, e.g. devices "confess" that there was an error. In other case people will stop using the technologies as they will not trust it anymore.
- **Transparent and clear information** has to be given in order to avoid any risk of resistance, feeling of manipulation among targeted user groups.
- Behaviour in groups seems to follow **tipping point effect** (phase change) with only few at first where soon followed by almost everyone. Activities should be designed by approach focused on **communities**. Behaviour change is a long-lasting process where new behaviours are created with **small steps.** ■

Partners:

References

[1] Tisov, A.; Veld, P.O. Introduction to the H2020 MOBISTYLE project, REHVA Journal, Dec 2018. URL – Available online: https://www.mobistyle-project.eu/en/mobistyle/dissemination/PublishingImages/mobistyle-publications/REHVA_Dec%202018.pdf (accessed on 20.07.2020).

[2] Tisov, A.; Olivadese R.; Arabsolgar D.; Margoudi M. REHVA Journal, Oct 2019. URL – Available online: https://www.mobistyle-project.eu/en/mobistyle/dissemination/PublishingImages/mobistyle-publications/REHVA_Oct_2019.pdf (accessed on 20.07.2020).

Schellen, L., van Marken Lichtenbelt, W.D., Loomans, M.G., Toftum, J., de Wit, M.H. Differences between young adults and elderly in thermal comfort, productivity, and thermal physiology in response to a moderate temperature drift and a steady-state condition. Indoor air. 2010;20(4):273-83.