A mixed-method approach: virtual reality to co-create future higher education workspaces in a post COVID-19 academic environment

Yolanda Rendón-Guerrero[1], Amy Bendall[2], Sean Jenkins[3], Ceri Phelps[4], Garry Bartlett[5], Paul Hutchings[6]

[1]Assistive Technologies Innovation Centre (ATiC)
y.rendon-guerrero@uwtsd.ac.uk
[2]Psychological Evaluation and Research Consultancy Hub (PERCH)
a.bendall@uwtsd.ac.uk
[3]Assistive Technologies Innovation Centre (ATiC)
sean.jenkins@uwtsd.ac.uk
[4]Psychological Evaluation and Research Consultancy Hub (PERCH)
ceri.phelps@uwtsd.ac.uk
[5]Assistive Technologies Innovation Centre (ATiC)
garry.bartlett@uwtsd.ac.uk
[6]Psychological Evaluation and Research Consultancy Hub (PERCH)
paul.hutchings@uwtsd.ac.uk

Abstract

The turmoil caused by COVID-19 saw academics and students in Higher Education (HE) institutions across the UK, and worldwide, facing the sudden and unplanned move to online or blended delivery. It left pre-pandemic operational models in need of evolving, leading to an opportunity to develop and test innovative architectural and spatial programming design strategies for 'knowledge work' spaces as academic staff and students returned to campus. The aim of this inter-disciplinary longitudinal study was to evaluate and validate a unique mixed-method approach, which combines extended reality, user experience (UX) and psychological research methodologies with architectural design strategies, to understand how people feel at work; how the environment influences their performance, health and wellbeing; and how to maximise spatial usage. Results were obtained by triangulating data collected from co-creation workshops, an ecological momentary assessment (EMA) survey, and a final usability virtual reality (VR) evaluation. Results imply that there is no ideal layout that would fulfil every user's needs, instead new strategies need to be developed for workspaces to be redesigned creatively following longer-term usability and healthy architecture standards. This includes the mixed-method approach in this study that successfully creates a link between disciplines and user groups: UX and psychological researchers, architects, estates managers and end-users.

Author keywords

Extended Reality; VR; User Experience; Co-creation Methodologies; Architectural Design.

Introduction

The COVID-19 pandemic has enforced a dramatic change to the working practices of millions of people across the UK and beyond, having a significant impact on many existing working practices, quality of life, and wellbeing. The impact of the unprecedented lockdowns on the nation's mental health is already being witnessed. Evidence from similar situations such as the SARS-CoV outbreak in 2003 predicts that there will be a global future impact on health and wellbeing with increased levels of stress, anxiety and depression amongst the population (Torales, et al., 2020). For those in employment during the pandemic, the significant changes to working practices and work-life balance associated with working from home led to increasing concerns about the ongoing impact of the pandemic on the wellbeing of the nation's workforce and the need to identify effective future working practices (Boland et al., 2020). Despite these challenges, many effective working practices emerged during this time driven by innovative service provision, which has been significantly felt amongst academics in Higher Education (HE) institutions across the UK; with the sudden and unplanned move to online delivery (either wholly or blended) and the rapid adaption of traditional academic roles and working practices. The concept of 'office fit' (the characteristics of the working environment and their interaction with the individual psychological and physiological characteristics and needs) has long been acknowledged as needing to be addressed by any organisation, for them to ensure their long-term survival (Shalley, et al., 2004). Traditionally, in HE, academic staff have been primarily seen to carry out what is termed 'knowledge work' (Drucker, 1959; Davenport, 2005); applying their mental faculties to understand ding and use of information, decision making, and with high levels of creativity (Oyetunji, 2014). Researchers have explored similarities between academic and commercial knowledge work and the influence of work-group space (Leaman and Bordass, 2006; Ashkanasy et al., 2014; Khoshbakht, et al., 2021), layout (Haynes, 2008) and activity-based prac-

tices (Engelen et al., 2019) on mental health, wellbeing and productivity (To et al., 2012). However, it is clear that pre-pandemic operational models need to evolve. Alternative approaches, that consider environment factors such as lighting, heating, and ventilation (Al Horr, et al., 2016; Lan, et al., 2012), or connection to natural elements (Jamrozik and Clements, 2019; Berman et al., 2008; Palacios et al., 2020), noise prevention (Jamrozik, et al. 2018), and privacy (Keeling et al., 2015), are required. These integrate existing and new working practices for future knowledge working, which maximise people's physical and cognitive functions (Jamrozik, et al., 2019), and prevent loss of interest (Whitley et al., 1996). The Well Spaces and Academic Environments (WellSPACE) Project is a collaboration study between the University of Wales Trinity Saint David's (UWTSD) Assistive Technologies Innovation Centre (ATiC) and the Psychological Evaluation and Research Consultancy Hub (PERCH) with renowned architectural practice Stride Treglown. This study tested a mixed-method approach of three phases (Figure 1) that introduce user experience (UX) and psychological research methodologies; implement extended reality; and investigate data correlation between environment control, health and wellbeing measures to assess the usability of various hypotheses of a HE space as staff returned to the campus in Swansea (Wales, UK) for the start of the academic year 2021/2022.

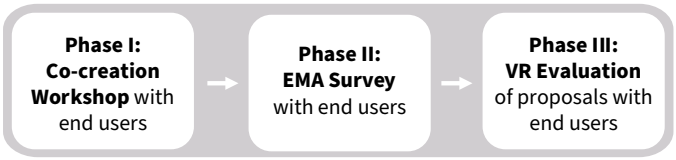

Figure 1. Phases of the mixed-method approach tested in this study.

Ultimately, we present this as a feasibility study of the application of this mixed-method approach as a novel architectural and spatial programming inter-disciplinary design strategy, which gives voice to end users throughout all stages of the study.

Mixed-method Approach

At the core of this study are end-users, academic staff who provided us with an insight into their own professional experiences in the engagement with workspaces, daily tasks, and students, to help us define how to redesign effective environments based on the conditions that affect people's physical and cognitive functions, as people tend to perform better when physically comfortable. Participants were encouraged to give feedback on how they feel at work, the spaces, furniture, layout, and footprint of these, and were challenged to suggest how to improve their experiences from a problem-solving approach. Shortly before the COVID-19 pandemic, the participant group had relocated to a new building which was purpose-built to accommodate an activity-based working typology – the 'IQ building' (UWTSD). This building comprises non-assigned workspaces, bookable meeting rooms and small pods for quiet working from an open-plan space that we call 'Room 303'. Post-pandemic, and during the study, participants had incorporated a hybrid workspace model, alternating working from home (WFH) with working on-site. The aim of this project was to identify the factors that affect mental health, wellbeing and performance of academic staff who have been assigned Room 303 as their workspace. For this, our team investigated the relationship between academic staff, their workplace, and the post-pandemic reconstruction that their practice was experiencing to support architectural design as an agent of change alongside end users. Our final outcome was the validation of data triangulation between the three phases of the study, explained below.

Phases of the study

During phase I, researchers implemented design thinking and UX methods. The workshop was divided into three activities that implemented methods such as mind mapping, place-centred user journey mapping, and participatory co-creation design (Figure 2A).

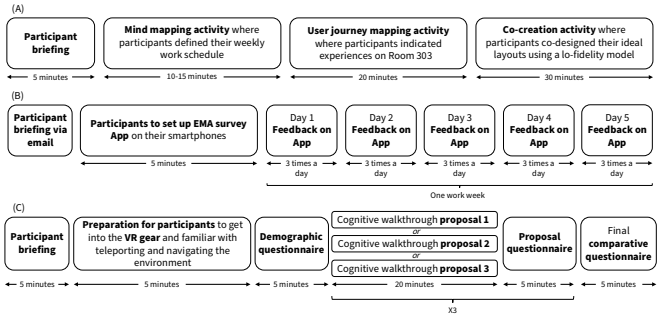

Figure 2. Protocols for (A) Phase I, (B) Phase II and (C) Phase III.

The ecological momentary assessment (EMA) survey, phase II, allowed us to collect data on end-user behaviour while working from their normal environments as explained in Figure 2B. Methods for data collection during this phase included experience sampling over a period, and exploratory analysis. The protocol for the final evaluation, phase III, (Figure 2C) included the use of VR and usability testing methods for qualitative and quantitative data collection – subjective VR walkthroughs, live observation and feedback questionnaires. The first two phases of the study informed the generation of three architectural proposals for the chosen test space Room 303 (Figure 3).

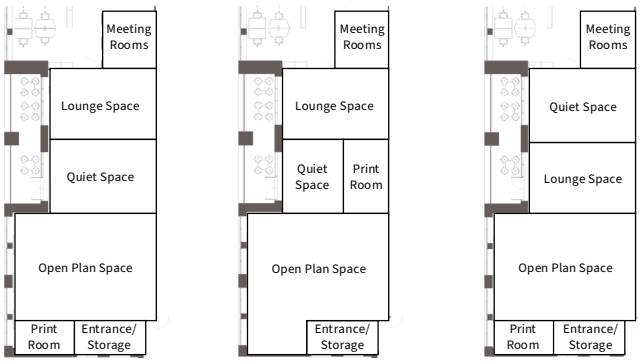

Figure 3. Architectural plan proposals for Room 3.
From left to right: proposals 1, 2 and 3.

Results

Data collected during the three phases was triangulated to identify the main findings of the study.

Phase I. UX metrics

Journeys mapped (Figure 4) helped us identify predominant use of Room 303 for 12 end-users over a two-day period and allowed us to investigate the correlation between the main activities and factors that influence their choices when working from this open plan space (Table 1).

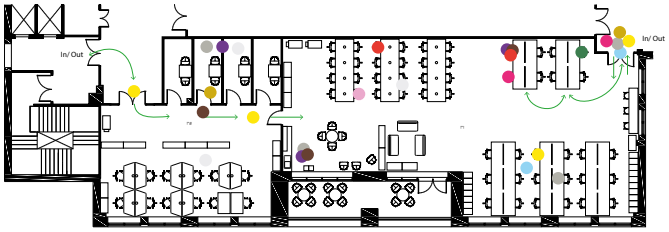

Figure 4. Participants' journeys were mapped on their use of Room 303 during co-creation workshops.

Table 1. End-user interaction with Room 303.

Activities mapped	Common influencing factors associated with low use of Room 303
Supervision/Emailing	No privacy; background/visual noise; and limited surface/power capacity.
Socialising/Having lunch	Fear of disturbing others; and limited kitchen storage.
Storing things/Printing	Insufficient storage units; and unclear allocation of these.

In general, there was discomfort in relation to some rooms. This was due to lack of ventilation, daylight, and connection to natural elements, which contribute negatively to performance. Through data collection on negative and positive variables (Figure 5A), we could recognise key objections in relation to spatial needs, which revolve around: privacy (e.g., pastoral care or data protection issues); accommodating unplanned use of Room 303 (and adjacent rooms); or managing ground rules (e.g., unsure of what is available for their use in the kitchen). Participants of the co-creation workshop demonstrated interest in getting involved on design decisions to improve the space by providing us with suggestions (Figure 5B), using a low fidelity model the groups generated five ideal layouts.

To inform subsequent work on behavioural assessment, the analysis of all the qualitative data collated during the co-creation workshops allowed us to group end users' needs into several salient themes (Table 2).

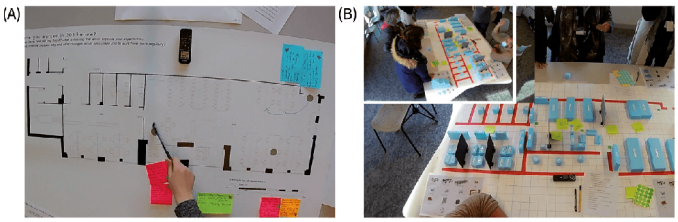

Figure 5. (A) Co-creation workshop feedback on negative and positive variables on Room 303, (B) example of layout co-designed by participants of the study using a low fidelity model.

Table 2. Salient themes captured from co-creation workshops.

Themes	Examples
Space	Quiet and private; community-building; and hybrid/hyflex teaching spaces.
Noise	Background and visual noise prevention.
Environment	Control over lighting, heating, ventilation and power; as well as more plants and daylight.
Storage	Personal/work belongings and food.
Management	Establish ground rules; identifiable furnishings; or hygiene and health & safety measures.

The lovely views of this workspace seemed to play a big role in ease of use of this workspace with those participants of the study sympathetic of open plan layouts enjoying working from Room 303; who found helpful building a sense of community and promotes teamwork. However, disparity in the feedback received implied that lighting and heating control and noise prevention remained prone to contentious issues between users.

Phase II. Behavioural assessment

For the phase II, EMA study, 55 responses were recorded from eight participants over a five-day period. Each respondent received 15 alerts across this period, with response rates ranging from 27% to 73% and an overall response rate of 46%. Table 3 shows primafrily on-campus activities, with comparative WFH data only presented to illustrate potential future design considerations. In our study, it is important to note that participants reported mainly WFH (65.5% of the time). The data presented in this section primarily focuses on data reported from on-campus activities, with comparative working from home data presented to illustrate potential future design considerations. Of those reporting working on campus (34.5%) the majority reported working in teaching rooms (14.5%) and non-shared spaces (14.5%) with a small number working at the on-campus library (3.6%). No participants reported using the shared workspace during the study period. Comparatively, Table 3 shows that whilst working from home, participants were most regularly engaged with preparation of teaching materials (22.2%), and least often engaged in online teaching (5.6%). The data indicates that the main reason for participants being on campus was for face-to-face teaching (50%), with associated teaching preparation being carried out on campus 16.7% of the time compared to 22.2% of the time at home. Of particular interest is the finding that no participants reported engaging in administrative or research-related tasks on campus.

Table 3. Activities undertaken during the working week.

Activity	WFH	On-campus
Teaching - Online	5.6%	5.6%
Teaching – Face to face	0%	50%
Student supervision - Online	8.3%	0%
Student supervision – Face to face	0%	5.6%
Meeting - Online	13.9%	5.6%
Taking a break	5.6%	5.6%
Marking	8.3%	5.6%
Preparing teaching materials	22.2%	16.7%
Admin tasks	16.7%	0%
Research related activity	11.1%	0%
Other	8.3%	5.3%
Total	100%	100%

Environmental disturbances, suitability, and control

Over the course of the study, participants indicated that they were being disturbed by one or more environmental factors 41% of the time. Of the overall on-campus disturbances, the most common were insufficient surface space and factors such as physical discomfort, feeling cold, and lack of access to resources, with the latter being reported significantly more often than WFH ($t(52) = -2.91$, $p = 0.005$). Table 4 indicates

that respondents reported generally similar levels of perceived environmental suitability across both on-campus locations and while WFH without significant differences across these locations. Participants also reported a generally high perceived level of control over their working environment WFH and in non-shared on-campus rooms. The lower level of control reported within the teaching rooms is indicative of the nature of teaching activity within the room but warrants further exploration.

Table 4. Mean scores of perceived environmental suitability and control across all responses.

Location	Suitability (0-5)	Control (0-10)
Working from home	3.7	7.7
On-campus teaching room	3.4	3.4
On-campus non-shared room	4.1	6.3
On-campus library	4	5

Wellbeing

Of the eight wellbeing factors captured during this phase of the study, the most endorsed overall while working on-campus were happiness and engagement (both M = 6.8). The lowest-reported factor was anxiety (M = 2.9), which was also significantly lower on campus than when WFH (M = 4.2, t (52) = 2.36, p = 0.02). Whilst the trends in the data suggest that engagement was often higher towards the end of the week than at the start with anxiety lowering over the course of the week. The individual variation in these wellbeing factors is an important reminder of the challenges of accounting for individual differences in the psychological facets of workplace design preferences.

Phase III. VR evaluation

Five academic staff from UWTSD participated in this phase of the study, whose main roles were lecturers or senior lecturers, between the ages of 35 and 58 years old. They had limited previous experience of using VR systems.

Participants

Demographic data gave us an indication of population-based factors representative of the academic community, that we could correlate with subsequent datasets collected more specific to spatial factors. We found that predominant work model was hybrid (80%), as opposed to working on-site (20%) or fully WFH (0%) (Figure 6A). Academic staff have rapidly adapted to hybrid working (Figure 6B), implying that depending on their main roles and time of the year, individuals need a flexible space that adapts to their changing needs.

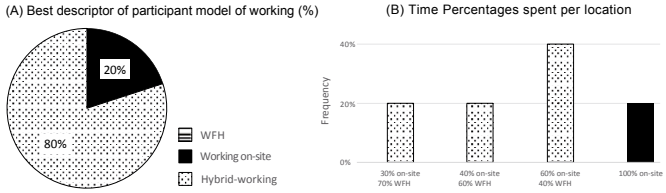

Figure 6. Participant working preference per (A) model of working and (B) location.

Data indicates that the main activities that academic staff undertake daily were teaching face-to-face; taking virtual meetings; marking; preparing teaching material; and administrative work (Figure 7). If we look reflectively upon previous findings from phases I and II, this data suggests a reiteration of certain factors. This includes the need for spaces to run one-to-one sessions on-site, teach within hyFlex facilities or catch up with colleagues.

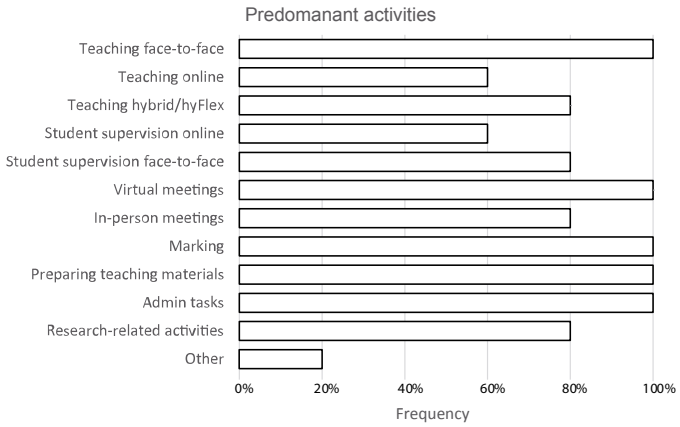

Figure 7. Predominant activities registered as undertaken by end-users daily.

VR walkthroughs

Using computer-generated environments of the original layout of Room 303 (Figure 8A) and of the three redesigned proposals (Figure 8B), participants were asked to navigate through each of the proposals in random order to evaluate their usability based upon factors defined from previous findings. Mixed reality (MR) played a big part in the protocol designed for the VR evaluation. Researchers generated computerised realistic representation of the architectural proposals using Unity development platform with high-end VR system HTC Vive Pro. To match VR simulation characteristics with that of the real world, this technology was combined with the use of physical furniture, embedding of audio recordings from the existing space, and photographic maps of the external views (Figure 8C). Participants' experience of the VR simulation was documented using internal VR recordings of their perspectives and external multi-camera recordings (Figure 8D) for post-processing.

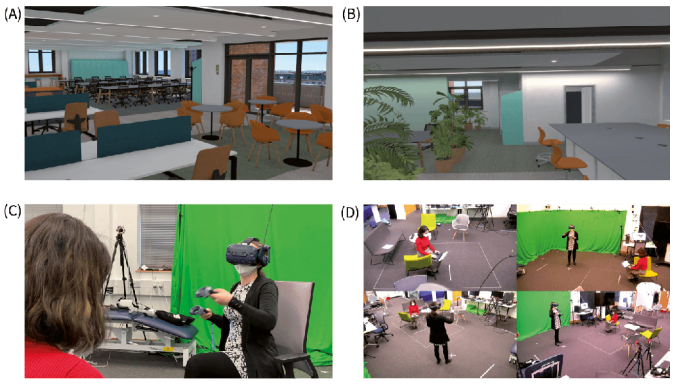

Figure 8. (A) VR representation of original layout of Room 303, (B) VR representation of proposal 1, (C) VR simulation with participant interacting with furniture, and (D) lab set up for VR simulation.

Data suggests that meeting spatial needs linked to privacy (e.g., one-to-one sessions with students or being able to provide hyFlex teaching) is still challenging for the three alterna-

tive proposals. However, there is a general agreement about the effectiveness of the proposals when it comes to meeting social needs. Personalisation and individual desking areas are very important for academic staff, where we have identified that it contributes towards a lack of sense of belonging. User footprint suggests that those whose practice is in proximity to Room 303 use this staff room more frequently, as opposed to those whose practice is disconnected to Room 303. Data shows that storage is a recurring challenge. In general, there is a tendency to prefer a variety of furniture within the same open-plan office space as opposed to having separate and crowded quiet areas.

Comparative between proposals

Following the physical and cognitive VR walkthroughs of the three proposals, previously designed by Stride Treglown, participants registered their preference in feedback questionnaires following a five-point Likert psychometric scale (Figure 9), which indicates that most participants tend towards the layout configured in proposal 1; very closely contested by proposal 3. Although the layout presented in proposal 2 did not satisfy participants as consistently as those in proposals 1 and 3, participants suggested that the variety of furniture choice available in this second configuration would pose an advantage for those who want to work more privately or within teams all in the same hybrid workspace.

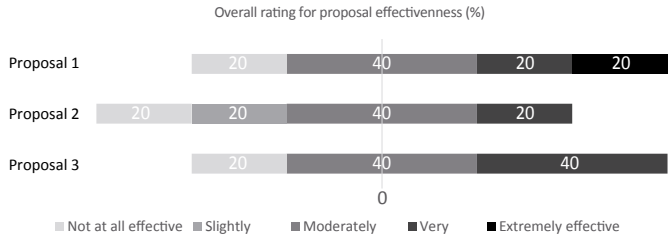

Figure 9. Overall participant rating of the effectiveness of the three alternative proposals presented.

Discussion

The triangulation between methods used in the three phases of the project direct us towards identifying the factors that impact academic staff behaviour, wellbeing, and performance, looking closely at the features of our test space, to inform future design strategies and decisions. However, there are other factors around user expectation (e.g., not feeling heard by management team) that may generate loss of interest in building community and could prevent the use of dedicated workspaces. Even though academic staff participating in this study were inclined towards one of the alternative architectural proposals designed for Room 303 during this study, data shows that this workspace would still present challenges when it comes to: accommodating one-to-one meetings, tutorials, or external guests; privacy for marking or dealing with student issues; and creating the right spaces for quiet working and online teaching on-site parallel to their pre-pandemic responsibilities. However, our intention with this study is to set out the pathway for future research approaches on investigating the features needed to overcome these challenges in pursuit of a workspace configuration that minimises the impact on the mental health, wellbeing, and performance of its users in relation to their practice.

When considering the future design of academic workspaces, therefore, in addition to continuing to support teaching and related activity, there is a need to better understand the barriers and requirements to supporting research and administrative activity in modern academic shared workspaces. Collectively, our results potentially suggest that hybrid working practices may help academic staff to fit their environmental location to the requirements of the specific task. Possibly, allowing academic staff to personalise part of the workspace assigned to their teams will help tackle issues around storage, as well as to allow Room 303 to turn into a hub for all academic staff from across disciplines. The challenge for the future design of academic workplaces is how to create the flexibility of workspaces to enable academics to engage with all aspects of their job roles in on-campus shared locations and consider individual preferences and motivations. Therefore, standardising design strategies that support this and allows for the implementation of research methods, such as those tested in this study, are needed at both early design stages and post-occupancy, to explore the longer-term effect of new spatial designs.

Going forward, the team intends to investigate further methods to quantify human response to changes in architectural features, where extended reality is fused with non-invasive techniques to measure and quantify psychophysiological responses longitudinally in conjunction with attitudinal and behavioural techniques validated in this study; and to continue exploring how a mixed-method approach can be further validated by testing it within alternative settings and user cohorts.

Conclusion

This inter-disciplinary study outlines an opportunity to systematically explore what the future of working spaces and practices should look like by testing these within a HE context to develop new and innovative architectural and spatial programming design strategies that can be translated to working environments in other creative, knowledge and professional service sectors. Due to COVID-19 restrictions we faced limitations on participant recruitment and managing their expectations where some may feel their voices have not been heard. Researchers have been aware of conflict of interests where possible to ensure transparency during research in the prevention of potential bias. With the c o-creation workshops (phase I), we identified users' needs – categorised by space types, storage, environment control, noise and management – and co-designed ideal layouts with end-users. The ecological momentary assessment (phase II) gave us an insight into how participants feel and behave when working from different environments over a work week. Finally, we evaluated the effectiveness of three alternative proposals for Room 303 where participants took part in a VR simulation (phase III). Results from the three phases, predominantly through formative evaluation, consistently show that end-user participation is hugely beneficial in developing design strategies essential for inclusive architecture. Overall, the data suggests that management plays a big role in ensuring that workspaces respond to the needs and footprint of different users throughout academic periods. This document focuses on such findings of this study that demonstrate the feasibility of the mixed-method approach implemented for the WellSPACE project. We conclude with a research agenda that advocates building on the positive results of this mixed-method approach by (a) introducing psychophysiological measures;

(b) maximising the implementation of mixed-reality; (c) and investigating data correlation between environment control, health and wellbeing in future research works.

Acknowledgments

We thank all the participants of this study, and all support from the collaborating teams, who met regularly and provided helpful feedback throughout the study. Special thanks to the Stride Treglown team who worked tirelessly amongst the team of researchers to redesign three ideal proposals of Room 303 to be evaluated with academic staff during this study. The research was undertaken as part of the Accelerate programme, co-funded by the European Regional Development Fund and the Welsh European Funding Office

References

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M., & Elsarrag, E. (2016). Occupant productivity and office indoor environment quality: A review of the literature. Building and environment, 105, 369-389.

Ashkanasy, N. M., Ayoko, O. B., & Jehn, K. A. (2014). Understanding the physical environment of work and employee behavior: An affective events perspective. Journal of Organizational Behavior, 35(8), 1169-1184.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. Psychological science, 19(12), 1207-1212.

Boland, B., De Smet, A., Palter, R., & Sanghvi, A. (2020). 2020 Reimagining the office and work life after COVID-19. The McKinsey Quarterly. Academic Service, 3, 58-68.

Davenport, T. H. (2005). Thinking for a living: how to get better performances and results from knowledge workers. Harvard Business Press.

Drucker, P. F. (1959). Landmarks of Tomorrow: A Report on the "Post-Modern" World. Piscataway, NJ: Transaction.

Engelen, L., Chau, J., Young, S., Mackey, M., Jeyapalan, D., & Bauman, A. (2019). Is activity-based working impacting health, work performance and perceptions? A systematic review. Building research & information, 47(4), 468-479.

Haynes, B. P. (2008). The impact of office layout on productivity. Journal of facilities Management.

Jamrozik, A., & Clements, N. (2019). Human Performance and Productivity in Buildings. ASHRAE Journal, 61(6), 73-77.

Jamrozik, A., Clements, N., Hasan, S. S., Zhao, J., Zhang, R., Campanella, C., ... & Bauer, B. (2019). Access to daylight and view in an office improves cognitive performance and satisfaction and reduces eyestrain: A controlled crossover study. Building and Environment, 165, 106379.

Jamrozik, A., Ramos, C., Zhao, J., Bernau, J., Clements, N., Wolf, T. V., & Bauer, B. (2018). A novel methodology to realistically monitor office occupant reactions and environmental conditions using a living lab. Building and Environment, 130, 190-199.

Keeling, T., Clements-Croome, D., & Roesch, E. (2015). The effect of agile workspace and remote working on experiences of privacy, crowding and satisfaction. Buildings, 5(3), 880-898.

Khoshbakht, M., Baird, G., & Rasheed, E. O. (2021). The influence of work group size and space sharing on the perceived productivity, overall comfort and health of occupants in commercial and academic buildings. Indoor and Built Environment, 30(5), 692-710.

Lan, L., Wargocki, P., & Lian, Z. (2012). Optimal thermal environment improves performance of office work. REHVA Journal, 49(1), 12-17.

Leaman, A., & Bordass, B. (2006). Productivity in buildings: the 'killer'variables. In Creating the productive workplace (pp. 181-208). Taylor & Francis.

Oyetunji, C. O. (2014). Lecturers' perceptions of open-plan office in tertiary institutions. Journal of Education and Training, 1, 28-38.

Palacios, J., Eichholtz, P., & Kok, N. (2020). Moving to productivity: The benefits of healthy buildings. PloS one, 15(8), e0236029.

Shalley, C. E., Zhou, J., & Oldham, G. R. (2004). The effects of personal and contextual characteristics on creativity: Where should we go from here?. Journal of management, 30(6), 933-958.

To, M. L., Fisher, C. D., Ashkanasy, N. M., & Rowe, P. A. (2012). Within-person relationships between mood and creativity. Journal of Applied Psychology, 97(3), 599.

Torales, J., O'Higgins, M., Castaldelli-Maia, J. M., & Ventriglio, A. (2020). The outbreak of COVID-19 coronavirus and its impact on global mental health. International journal of social psychiatry, 66(4), 317-320.

Whitley, T., Dickson, D. and Makin, P., 1996. The contribution of occupational and organisational psychology to the understanding of sick building syndrome. In CIBSE/ASHRAE Joint National Conference (pp. 133-138).