frontiers | Frontiers in Built Environment

TYPE Editorial
PUBLISHED 22 November 2022
DOI 10.3389/fbuil.2022.1095443

OPEN ACCESS

EDITED AND REVIEWED BY
Hazim Bashir Awbi,
University of Reading,
United Kingdom

*CORRESPONDENCE
Fan Zhang,
fan.zhang@griffith.edu.au

SPECIALTY SECTION
This article was submitted to Indoor Environment,
a section of the journal
Frontiers in Built Environment

RECEIVED 11 November 2022
ACCEPTED 14 November 2022
PUBLISHED 22 November 2022

CITATION
Zhang F, Liu S, Hu W and Yadav M (2022), Editorial: Effects of indoor environmental quality on human performance and productivity.
Front. Built Environ. 8:1095443.
doi: 10.3389/fbuil.2022.1095443

Editorial: Effects of indoor environmental quality on human performance and productivity

Fan Zhang[1]*, Shichao Liu[2], Wenye Hu[3] and Manuj Yadav[3,4]

[1]School of Engineering and the Built Environment, Griffith University, Southport, QLD, Australia, [2]Department of Civil, Environmental, and Architectural Engineering, Worcester Polytechnic Institute, Worcester, MA, United States, [3]School of Architecture, Design and Planning, The University of Sydney, Sydney, NSW, Australia, [4]Institute for Hearing Technology and Acoustics, RWTH Aachen University, Aachen, Germany

KEYWORDS

indoor environment quality (IEQ), indoor air quality (IAQ), acoustics, lighting, performance and productivity, energy efficiency

Editorial on the Research Topic
Effects of indoor environmental quality on human performance and productivity

Indoor environment quality (IEQ) closely relates to the health and wellbeing of persons who use the space there (The National Institute for Occupational Safety and Health, 2013). Indoor air quality (IAQ), thermal comfort, lighting comfort, and acoustic comfort are the four primary IEQ factors. Previous research demonstrates that the quality of a building's indoor environment significantly affects occupants' health (Hoskins, 2003), satisfaction (Cheung et al., 2021), comfort and wellbeing (Al Horr et al., 2016a), as well as cognitive function and productivity (Al Horr et al., 2016b; Wang et al., 2021) The IEQ is also significantly associated with the energy use and efficiency of buildings (Roumi et al., 2021). Due to the IEQ domain's highly applied nature, the focus has been placed on creating connections between physical indoor environmental parameters and human responses as a means of improving building management, operation, and control (Zhang et al., 2019). Although the quantitative relationships between IEQ and human responses are not well understood, there is no doubt that desirable IEQ exerts a positive impact on building occupants (Sakellaris et al., 2016).

However, many residential, commercial, and industrial buildings do not have satisfying IEQ (Kubba, 2016). Common problems can include thermal discomfort (Liu et al., 2017), poor air quality due to indoor air pollutants and/or insufficient ventilation (Rajagopalan et al., 2022), insufficient daylight and reflection/glare issues (Hamedani et al., 2019), and auditory distraction (Yadav et al., 2017), which may in turn adversely affect occupants and building energy efficiency (Hu & Davis, 2021; Roumi et al., 2022). Building on the existing initiatives, this research topic Research Topic aims to present new research evidence in monitoring and assessing IEQ parameters, and propound new methods and perspectives in addressing IEQ issues and reducing the

negative impact on building occupants. The research topic collects five articles in IAQ, lighting, and acoustics areas, including three original research articles, one review, and one perspective.

In recent years, there has been a growing concern about toxic chemical compounds released from building materials and household items into indoor spaces (Suzuki et al., 2019). Building materials frequently contain chemicals that continue to emit or "off-gas" after installation for extended periods of time. The first paper examines the indoor air pollutants of new high-rise apartments in Dubai. Jung et al. conducted an on-site measurement of the volatile organic compounds (VOCs) concentration in nine new apartments with different layouts and finishing materials. They also carried out a laboratory experiment to continuously monitor the VOCs concentration for 30 days. The results provide a rational basis for Dubai municipality to regulate the IAQ in new apartment buildings.

The second paper is a related IAQ field monitoring study in Dubai's residential buildings. Jung et al. (2022) investigated and compared the concentration of common indoor air pollutants in six households in a residential area with that of five households in an industrial area. Effects of confounding variables were also examined, including dwelling size, outdoor pollution concentration, time after construction, type of finishing materials, indoor temperature and relative humidity, and type of furniture, appliances, and fixtures. Results show that building materials' emissions of indoor air pollutants decreased 18 months after the construction. However, the formaldehyde concentration can still exceed the IAQ standard level thus representing a long-term IAQ problem for all dwellings.

Light, the most important entrainment cue for circadian rhythms, can reduce occupants' fatigue and sleepiness and, consequently, improve occupants' performance in workplaces. A growing body of literature investigated how light influences occupants' productivity, alertness, task performance, and cognitive functions, but some led to mixed results. The third paper, Wang and Zhao, reviewed forty-five studies and provided a systematic understanding of the non-image-forming (NIF) effect of light. One objective indicator, post-illumination pupil response, could be potentially used in field studies investigating NIF, since it is non-invasive and faster, compared to electroencephalogram measurements, and melatonin measurements in plasma or saliva.

In buildings, occupants' performance and productivity are influenced by the light entering their eyes, in the context of the entire lighting environment. Conventional lighting design strategies only focus on the light on horizontal planes since horizontal illuminance is required by most national and international standards. Concerns have been raised that vertical illuminance at eye levels should be considered to evaluate glare and the circadian effect of lighting. The light that does not enter occupants' eyes is wasted as it does not contribute to either visual perception or NIF. In the fourth paper, Durmus et al. proposed a framework to evaluate lighting more holistically. This new framework can help better assess lighting design solutions and quantify both energy efficiency and visual quality of the illuminated space.

Lately, the use of active noise cancellation (ANC) headphones has been garnering substantial interest as a potential coping mechanism against intelligible speech, which represents a major contributor towards dissatisfaction with open-plan offices. There is, however, very limited research investigating the cognitive and subjective effects of using ANC headphones in office settings, which is addressed in the fifth paper. Mueller et al. simulated intelligible speech from various locations in an office, which was presented to participants across several settings in a laboratory experiment. The results showed no significant effect of ANC being on or off on short-term memory performance although wearing ANC headphones significantly improved subjective aspects such as perceived privacy and the assessment of the acoustic environment. These results highlight the complicated nature of assessing occupants' performance in offices in relation to the use of ANC headphones.

The variety of research areas and topics in these five papers highlight the extensive research interests and efforts in improving buildings' IEQ and subsequently building occupants' health and wellbeing, comfort, and productivity. Yet, there are still a plethora of unknowns in this field waiting for future research studies to unveil, especially the combined effects of IEQ factors on building occupants, and how the weakest performing IEQ factors affect occupants' overall IEQ perception.

Author contributions

FZ and SL contributed to the conception of this editorial. FZ wrote the first draft. WH and MY wrote the lighting and acoustic sections of the manuscript. All authors contributed to the manuscript revision, read, and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Al Horr, Y., Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., and Elsarrag, E. (2016a). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *Int. J. Sustain. Built Environ.* 5 (1), 1–11. doi:10.1016/j.ijsbe.2016.03.006

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M., and Elsarrag, E. (2016b). Occupant productivity and office indoor environment quality: A review of the literature. *Build. Environ.* 105, 369–389. doi:10.1016/j.buildenv.2016.06.001

Cheung, T., Schiavon, S., Graham, L. T., and Tham, K. W. (2021). Occupant satisfaction with the indoor environment in seven commercial buildings in Singapore. *Build. Environ.* 188 (2020), 107443. doi:10.1016/j.buildenv.2020.107443

Hamedani, Z., Solgi, E., Skates, H., Hine, T., Fernando, R., Lyons, J., et al. (2019). Visual discomfort and glare assessment in office environments: A review of light-induced physiological and perceptual responses. *Build. Environ.* 153, 267–280. doi:10.1016/j.buildenv.2019.02.035

Hoskins, J. A. (2003). Health effects due to indoor air pollution. *Indoor Built Environ.* 12 (6), 427–433. doi:10.1177/1420326X03037109

Hu, W., and Davis, W. (2021). Toward a connected system—understanding the contribution of light from different sources on occupants' circadian rhythms. *Appl. Sci.* 11 (21), 9939. doi:10.3390/app11219939

Jung, C., Alqassimi, N., and El Samanoudy, G. (2022). The comparative analysis of the indoor air pollutants in occupied apartments at residential area and industrial area in dubai, united arab emirates. *Frontiers in Built Environment* 8. doi:10.3389/fbuil.2022.998858

Kubba, S. (2016). Indoor environmental quality (IEQ). *LEED v4 Pract. Certif. Accreditation Handb.*, 303–378. doi:10.1016/B978-0-12-803830-7.00007-4

Liu, S., Schiavon, S., Kabanshi, A., and Nazaroff, W. W. (2017). Predicted percentage dissatisfied with ankle draft. *Indoor Air* 27(4), 852–862. doi:10.1111/ina.12364

Rajagopalan, P., Andamon, M. M., and Woo, J. (2022). Year long monitoring of indoor air quality and ventilation in school classrooms in Victoria, Australia. *Archit. Sci. Rev.* 65 (1), 1–13. doi:10.1080/00038628.2021.1988892

Roumi, S., Stewart, R. A., Zhang, F., and Santamouris, M. (2021). Unravelling the relationship between energy and indoor environmental quality in Australian office buildings. *Sol. Energy* 227, 190–202. doi:10.1016/j.solener.2021.08.064

Roumi, S., Zhang, F., Stewart, R. A., and Santamouris, M. (2022). Commercial building indoor environmental quality models: A critical review. *Energy Build.* 263, 112033. doi:10.1016/j.enbuild.2022.112033

Sakellaris, I. A., Saraga, D. E., Mandin, C., Roda, C., Fossati, S., de Kluizenaar, Y., et al. (2016). Perceived indoor environment and occupants' comfort in European "modern" office buildings: The OFFICAIR study. *Int. J. Environ. Res. Public Health* 13 (5), 444. doi:10.3390/ijerph13050444

Suzuki, N., Nakaoka, H., Hanazato, M., Nakayama, Y., Tsumura, K., Takaya, K., et al. (2019). Indoor air quality analysis of newly Built houses. *Int. J. Environ. Res. Public Health* 16 (21), 4142. doi:10.3390/ijerph16214142

The National Institute for Occupational Safety and Health (2013). *Centres for disease control and prevention*. Available at: https://www.cdc.gov/niosh/topics/indoorenv/default.html#:~:text=Overview.

Wang, C., Zhang, F., Wang, J., Doyle, J. K., Hancock, P. A., Mak, C. M., et al. (2021). How indoor environmental quality affects occupants' cognitive functions: A systematic review. *Build. Environ.* 193 (15), 107647. doi:10.1016/j.buildenv.2021.107647

Yadav, M., Kim, J., Cabrera, D., and de Dear, R. (2017). Auditory distraction in open-plan office environments: The effect of multi-talker acoustics. *Appl. Acoust.* 126, 68–80. doi:10.1016/j.apacoust.2017.05.011

Zhang, F., de Dear, R., and Hancock, P. (2019). Effects of moderate thermal environments on cognitive performance: A multidisciplinary review. *Appl. Energy* 236 (15), 760–777. doi:10.1016/J.APENERGY.2018.12.005