



**HAL**  
open science

# Construction of immersive and interactive methodology based on physiological indicators to subjectively and objectively assess comfort and performances in work offices

Charlotte Scarpa, Gwénaëlle Haese, Toinon Vigier, Patrick Le Callet

## ► To cite this version:

Charlotte Scarpa, Gwénaëlle Haese, Toinon Vigier, Patrick Le Callet. Construction of immersive and interactive methodology based on physiological indicators to subjectively and objectively assess comfort and performances in work offices. Immersive media experience (IMX), Jun 2023, Nantes, France. 10.1145/3573381.3597233 . hal-04617871

**HAL Id: hal-04617871**

**<https://hal.science/hal-04617871>**

Submitted on 19 Jun 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Construction of immersive and interactive methodology based on physiological indicators to subjectively and objectively assess comfort and performances in work offices

Charlotte Scarpa

Laboratoire PULSE - Centre Scientifique et Technique du  
Bâtiment, 44300 Nantes ; Nantes Université, École  
Centrale Nantes, CNRS, LS2N, UMR 6004, F-44000 Nantes  
France  
charlotte.scarpa@cstb.fr

Toinon Vigier

Nantes Université, École Centrale Nantes, CNRS, LS2N,  
UMR 6004, F-44000 Nantes  
France  
toinon.vigier@univ-nantes.fr

Gwénaëlle Haese

Laboratoire PULSE - Centre Scientifique et Technique du  
Bâtiment, 44300 Nantes  
France  
gwenaelle.haese@cstb.fr

Patrick Le Callet

Nantes Université, École Centrale Nantes, CNRS, LS2N,  
UMR 6004, F-44000 Nantes  
France  
patrick.lecallet@univ-nantes.fr

## ABSTRACT

The building sector and the indoor environment conception is undergoing major changes. There is a need to reconsider the way offices are built from a user's centric point of view. Research has shown the influence of perceived comfort and satisfaction on performance in the workplace. By understanding how multi-sensory information is integrated into the nervous system and which environmental parameters influence the most perception, it could be possible to improve work environments. With the emergence of new virtual reality (VR) and augmented reality (AR) technologies, the collection and processing of sensory information is rapidly advancing, moving forward more dynamic aspects of sensory perception. Through simulated environments, environmental parameters can be easily manipulated at reasonable costs, allowing control and guiding the user's sensory experience. Moreover, the effects of contextual and surrounding stimuli on users can be easily collected throughout the test, in the form of physiological and behavioral data. Through the use of indoor simulations, this doctoral research goal is to develop a multi-criteria comfort scale based on physiological indicators under performance constraints. In doing this, it would be possible to define new quality indicators combining the different physical factors adapted to the uses and space. In order to achieve the objectives of this project, the first step is to develop and validate an immersive and interactive methodology for the assessment of multisensory information on comfort and performance in work environments.

## ACM Reference Format:

Charlotte Scarpa, Gwénaëlle Haese, Toinon Vigier, and Patrick Le Callet. 2023. Construction of immersive and interactive methodology based on

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

*IMX '23, June 12–15, 2023, Nantes, France*

© 2023 Copyright held by the owner/author(s).

ACM ISBN 979-8-4007-0028-6/23/06.

<https://doi.org/10.1145/3573381.3597233>

physiological indicators to subjectively and objectively assess comfort and performances in work offices. In *ACM International Conference on Interactive Media Experiences (IMX '23)*, June 12–15, 2023, Nantes, France. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3573381.3597233>

## 1 INTRODUCTION AND CONTEXT

The building sector and the way the indoor environment is conceived is undergoing major changes. It is a primordial sector considering that the majority of the world's population lives in urban areas and this number is expected to increase by two-thirds over the next 30 years [1]. According to a study conducted by the European World Health Organization, in 2013 [2], people spend a large majority of their life (>90%) in indoor environments. This progressive detachment from nature has proven to have a series of negative impacts on people's satisfaction, well-being, and productivity [3,4]. In future years, with the worsening of climatic conditions, we can

expect human life to become more dependent on artificial environments. Most of the buildings today are not adapted to the changes of tomorrow. Some of the responses will play out in how built spaces are designed, constructed, used, maintained, and retrofitted. Collectively, buildings in the EU are responsible for 40% of our energy consumption and 36% of greenhouse gas emissions, which mainly stem from construction, usage, renovation, and demolition. Improving energy efficiency in buildings, therefore, has a key role to play in achieving the ambitious goal of carbon neutrality by 2050, set out in the European Green Deal [5]. To reach these goals, the main course of action is the complete and efficient renovation of building stocks, thus supporting rapid technology development. Moreover,

since Covid-19 there has been a shift in our work-related habits. In fact, three years after the pandemic, the prior mono model of the workplace setting is no longer an option both for employees and companies and different and more flexible working systems have proven more efficient. Telework has proven effective for cost reduction, motivation, and work-life balance of workers and increases productivity and overall performance [6]. Because of these important changes in work practices, physical offices and the design of

buildings themselves also have to adapt and develop accordingly with the new shift of paradigm. It is a challenge for the building sector since there is the need of creating smart workplaces that take into account user's physiological and psychological reactions to different environmental cues. Future offices are likely to have

smarter and healthier environments, which make the most of environmental conditions, as well as societal changes. Today, models of hybrid work, as well as employee engagement are two important priorities. The nature of the work environment adapts to the needs of society and companies; most employees want to be in the conditions to decide where, when, and how they are working. Thus, facility managers and professionals of the work environment have to conceive flexible and functional buildings that offer at the time collaborative opportunities and quieter spaces to increase satisfaction in the workplace environment. Therefore, there is a need to reconsider the way offices are built in addition to a sustainability point of view, also from a user's centric point of view. [7,8]

## 2 CONTEXTE

In light of this challenge, this research seeks to understand the impact of environmental parameters (light, odor, sound, layout, etc...) on human declarative and non-declarative clues. In order to acknowledge the way people interact with the environment and tackle the extent of its influence on cognition and behavior, it is important to address the understanding of the sensory system and develop an efficient methodology capable of studying it. Sensory science is the multidisciplinary field at the origin of this issue and it comprises the measurement, interpretation, and understanding of human responses to product properties as perceived by the senses such as sight, smell, taste, touch, and hearing [9]. By understanding how sensory information is processed and integrated, it would be easier to promptly answer background industry questions and guide several strategies of renovation and construction from the standpoint of users. Sensory science has relied for many years on

the classical methods of sensory evaluation, through the collection of subjective perception, which can be modulated by a range of internal and external factors, such as expectations, context, memory, attention, etc..., for many aspects can be biased and do not always translate the full range of feelings and perceptions. Therefore, the best way to apprehend the cognitive, physiological, and emotional aspects of perception in the design, and interpret the effect of multisensory information on humans is by combining different levels of investigation. In recent years, with the progress in neuroscience, sensory science has been rapidly expanding in multiple and different scopes. Thanks to new methods, tools, and abundant research in this area, physiological data can now be measured and interpreted easily and more reliably, which, coupled with declarative methodology and cognitive assessments, gives us increased access to human insights [10]. The building sector has had yet to rely on

sensory science and the different methods of satisfaction assessment to propose user's centric design that reckon with how the combination of environmental stimuli can affect perception and cognition. Research has shown the influence of perceived comfort and satisfaction on performance in the workplace. It is yet still unclear which mechanisms are the most involved in cognition and

to what extent elements of the environment take part in this process [11,12]. Furthermore, with multisensory integration, we are aware that sensory modalities compensate each other, and that elements of the environment can be improved, by understanding how external information is integrated into the nervous system. By approaching this issue, we realize the struggle in setting up an experience to study multisensory information of the indoor environment. These kinds of tests include many different independent and dependent variables that need to be controlled as best to avoid methodological biases and other possible external effects. Furthermore, a massive amount of data that ought to be intersected and interpreted is generated and it requires full confidence in the data collection in order to make any kind of recommendation [13]. With the emergence of new virtual reality (VR) and augmented

reality (AR) technologies, the collection and processing of sensory information is rapidly advancing, moving forward more dynamic aspects of sensory perception, taking account of user-product interactions globally [14]. In indoor environment evaluations, simulated reality offers new possibilities for experimental design as well as a functional rapprochement between the laboratory and real life. In fact, with simulated environments, environmental parameters can be easily manipulated at reasonable costs, allowing to control and guide the user's sensory experience. Effects of contextual and surrounding stimuli on users can be easily collected throughout the test, in the form of physiological and behavioral data [15], without breaking the feeling of presence. Moreover, a realistic immersive VR environment can elicit vivid perceptual experiences, inducing a strong sense of presence and embodiment [16]. One main challenge is to acknowledge to which extent simulated environments are ecologically valid and which functions would be more solicited in different environmental simulation display formats. Previous works indicate that psychological and physiological responses can differ from natural to simulated content [17,18]. There is a need to estimate those differences in order to create viable environments to properly represent real-life simulated conditions, as well as adapted cognitive tasks.

## 3 THE AIMS, OBJECTIVES AND SCOPE OF THE RESEARCH

This doctoral research's final goal is to develop a multi-criteria comfort scale based on physiological indicators under performance constraints. In doing this, it would be possible to define new quality indicators combining the different physical factors adapted to the uses and spaces. In order to face this multidisciplinary subject, this 3 years research will include the following objectives:

- (1) Develop a media interactive methodology for the investigation of users comfort and performances in simulated environments
- (2) Define the comfort threshold of multi-sensorial clues
- (3) Define new quality physiological indicators by modeling the data

As indicated above, the development and validation of a straightforward methodology for the assessment of multisensory information on comfort and performance in an indoor environment is the first step needed to conduct the research. This new tool could be of

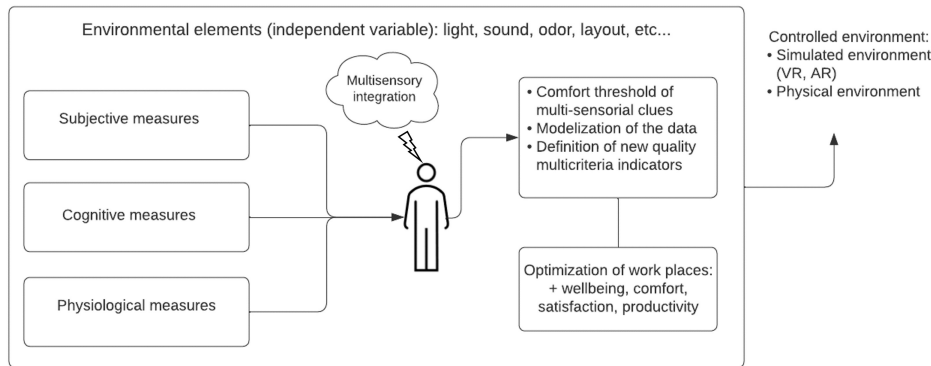


Figure 1: Schematic representation of the research framework

benefit, on one hand for methodological facilitation purposes and on the other for cost reductions.

#### 4 THE METHODS AND FUTURE WORK

In order to achieve the objectives of this project, the first step is to develop and validate the indoor simulations. In environmental simulations, one of the most used formats, for its visual realism and ease of use are 360° panoramic photos and videos, which permit capturing physical-world images. This format is projected in the head-mounted display (HDM) in a spherical format and the observer finds himself optically in the center of the sphere. Spherical panoramas are suited for the majority of motifs and allow an unrestricted view of the image in both horizontal and vertical directions [19]. Research identified a strong correlation between psychological responses and physical environment, as opposed to VR, because of their smaller degree of realism, but a stronger degree of sense of presence [20]. The HDM allows a fully-immersive system that isolates the user's senses from the external world and gives a higher degree of immersion. It also allows interesting associations between photographic techniques and VR, making them more interactive and immersive when combined with an HDM. Because of the great level of realism offered by real-world images, this research will include 360° photos of workplaces, taken with the 'Insta360Pro' camera and adapted to be seen in a head-mounted display via the software Unity. To increase embodiment, some virtual objects or assets (office table, computer etc...), will be added to the scene with a goal of interaction of the observer with the environment. Elements of the scene, such as light, color, and intensity will eventually be edited, to observe the disparate environmental effects on perception. We expect this mixed simulation to offer a fair compromise between the physical and simulated environments and to allow for an ideal validity of the format. A test will be undertaken with the objective to compare physical and simulated environments and assess the validity of the latter. Through the test, physiological data such as electrodermal activity, heart rate and eye movement will be collected. This test will allow on one hand to evaluate the validity of the format and on the other to compare office layouts. Moreover, it will allow us to apply the former methodology to different research

investigating specific environmental clues and sensory dimensions. For example, the 'Centre Scientifique et Technique du Bâtiment' (CSTB) is undertaking a test investigating the effect of the vibroacoustic phenomena on comfort and cognition. This methodology would permit further exploration of the vibroacoustic disturbance when multiple environmental stimuli are included. Such potential of multisensory investigation would permit the definition of new quality indicators for the building sector, as a last objective of this research.

#### 5 MAIN CONTRIBUTION(S) TO IMX

Interactive media experience, VR, and AR offer enormous potential in disparate sectors for the investigation of human behavior and for the development of user-centric designs. This research gives the possibility to investigate multisensory integration and understand how users interact with simulated environments compared with real life. The methodology conceived could not only benefit the building sector, but different disciplines that have to control multiple variables and wish to maintain ecological conditions. Most sectors, starting with sensory science have the potential to greatly evolve by the exploitation and exploration of new interactive technologies.

#### 6 BIBLIOGRAPHY

- (1) United Nations, Department of Economic and Social Affairs, Population Division. 2019. World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). New York: United Nations.
- (2) World Health Organization. Regional Office for Europe. 2014. Combined or multiple exposure to health stressors in indoor built environments: an evidence-based review prepared for the WHO training workshop "Multiple environmental exposures and risks": Bonn, Germany.
- (3) Chien-Fei Chen, Selin Yilmaz, Anna Laura Pisello, Marilena De Simone, Amy Kim, Tianzhen Hong, Karol Bandurski, Mateus V. Bavaresco, Pei-Ling Liu, and Yimin Zhu. 2020. The impacts of building characteristics, social psychological and cultural factors on indoor environment

- quality productivity belief. United States: N. p., Web DOI: 10.1016/j.buildenv.2020.107189.
- (4) Jonathan M. Samet, John D. Spengler. 2003. Indoor environments and health: moving into the 21st century. *Am J Public Health*. 93(9):1489-93. DOI: 10.2105/ajph.93.9.1489.
  - (5) European Commission – Department: Energy – In focus. Energy efficiency in buildings. Brussels, 17 February 2020
  - (6) Tronco Hernández YA, Parente F, Faghy MA, Roscoe CMP, Maratos FA. 2021. Influence of the COVID-19 Lockdown on the Physical and Psychosocial Well-being and Work Productivity of Remote Workers: Cross-sectional Correlational Study. *JMIRx Med*. 1;2(4):e30708. DOI: 10.2196/30708.
  - (7) S. Bicer and F.H. Halicioglu. 2022. Rethinking the influence of the Intelligent Building Systems on productivity, health, and well-being for enhancing the quality of life during mandatory working from home: Lessons learned from the COVID-19 pandemic. *IOP Conf. Ser.: Earth Environ. Sci.* 1101 032001. DOI: 10.1088/1755-1315/1101/3/032001
  - (8) Tarigan Surya Gunanta, Mannan Khalid Abdul, Uddin Nur. 2022. A study of work-culture changes at post Covid-19 pandemic in greater Jakarta. *IOP Conf. Ser.: Earth Environ. Sci.* 1098 012028. DOI: 10.1088/1755-1315/1098/1/012028
  - (9) Magni Martens. 1999. A philosophy for sensory science. *Food Quality and Preference*. Volume 10, Issues 4–5, Pages 233-244, ISSN 0950-3293
  - (10) Damir D Torrico, Annu Mehta, Amália Bernardes Borssato. 2023. New methods to assess sensory responses: a brief review of innovative techniques in sensory evaluation, *Current Opinion in Food Science*, Volume 49, 100978, ISSN 2214-7993. DOI: <https://doi.org/10.1016/j.cofs.2022.100978>
  - (11) Chao Wang, Fan Zhang, Julian Wang, James K. Doyle, Peter A. Hancock, Cheuk Ming Mak, Shichao Liu. 2021. How indoor environmental quality affects occupants' cognitive functions: A systematic review, *Building and Environment*, Volume 193, 107647, ISSN 0360-1323. DOI: <https://doi.org/10.1016/j.buildenv.2021.107647>.
  - (12) Sandra G. L. Persiani, Kobas Bilge, Sebastian Clark Koth, and Thomas Auer. 2021. "Biometric Data as Real-Time Measure of Physiological Reactions to Environmental Stimuli in the Built Environment" *Energies* 14, no. 1: 232. DOI: <https://doi.org/10.3390/en14010232>
  - (13) Cornelio Patricia, Velasco Carlos, Obrist Marianna. 2021. Multisensory Integration as per Technological Advances: A Review. *Frontiers in Neuroscience*, 15. ISSN=1662-453X. DOI: <https://doi.org/10.3389/fnins.2021.652611>
  - (14) Emily Crofton, Cristina Botinestean, M. Felon and Eimear Gallagher. 2019. Potential applications for virtual and augmented reality technologies in sensory science, *Innovative Food Science and Emerging Technologies*. Volume 56, 102178, ISSN 1466-8564. DOI: 10.1016/j.ifset.2019.102178
  - (15) Halbig Andreas, Latoschik Marc Erich. 2021. A Systematic Review of Physiological Measurements, Factors, Methods, and Applications in Virtual Reality, Volume 2, 2673-4192. DOI: 10.3389/frvir.2021.694567
  - (16) Dominik Gall, Daniel Roth, Jan-Philipp Stauffert, Julian Zarges and Marc Eric Latoschik. 2021. Embodiment in Virtual Reality Intensifies Emotional Responses to Virtual Stimuli. *Front Psychol*. 6;12:67417. DOI: 10.3389/fpsyg.2021.674179
  - (17) Juan Luis Higuera-Trujillo, Juan López-Tarruella Maldonado, Carmen Llinares Millán. 2017. Psychological and physiological human responses to simulated and real environments: A comparison between Photographs, 360° Panoramas and Virtual Reality, *Applied Ergonomics*, 65, 398-409, ISSN 0003.6870. DOI: 10.1016/j.apergo.2017.05.006
  - (18) Dongwoo Yeom, Joon-Ho Choi, Sin-Hwa Kang. 2019. Investigation of the physiological differences in the immersive virtual reality environment and real indoor environment: Focused on skin temperature and thermal sensation, *Building and Environment*, 154, 44-54, ISSN 0360-1323. DOI:10.1016/j.buildenv.2019.03.013.
  - (19) Corinna Jacobs. 2004. *Interactive Panoramas: Techniques for Digital Panoramic Photography*. Springer, Heidelberg, Germany. ISBN: 978-3-642-18665-3. DOI: 10.1007/978-3-642-18665-3
  - (20) Javier Marín-Morales, Juan Luis Higuera-Trujillo, Alberto Greco, Jaime Guixeres, Carmen Llinares, Claudio Gentili, Enzo Pasquale Scilingo, Mariano Alcañiz and Gaetano Valenza. 2019. Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum. *PLoS ONE* 14(10): e0223881. DOI: 10.1371/journal.pone.0223881