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Use of immersive and interactive systems to objectively and subjectively characterize user experience in work places

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ABSTRACT

This demo's objective is to display how simulated environments can be used in the evaluation of work-related indoor environments compared to physical environments. In fact, in indoor environment evaluations, Virtual Reality (VR) offers new possibilities for experimental design as well as a functional rapprochement between the laboratory and real life. With VR, environmental parameters (e.g light, color, furniture. . .) can be easily manipulated at reasonable costs, allowing to control and guide the user's sensorial experience. 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. User-centric evaluation and sensory analysis in the building sector is in its beginning; this new tool could be of benefit for the building sector, on one hand for methodological facilitation purposes and on the other for cost reductions. In order to achieve the objectives of this project, a 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 permits capturing physical-world images. In an objective of validation of the format, 360° photos of workplaces were taken in the building of Halle 6 Ouest of Nantes University and an immersive and interactive test based on physiological indicators to subjectively and objectively assess comfort and performances in work offices was developed. The demo will comprise a head-mounted display with integrated eye-tracking and the measure of electrodermal activity, heart rate and galvanic skin response.

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1 INTRODUCTION

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 number has largely increased and is expected to increase, as human life becomes more dependent on artificial 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] and therefore, indoor places must support 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 increase in productivity and overall performances [5]. 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.

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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 work-place environments. Therefore, there is a need to reconsider the way offices are built from a user's centric point of view. [6,7]

The building sector has yet to rely on sensory science and the different methods of satisfaction assessment to propose user's centric design that reckon with how environmental stimuli (e.g sound, odor, light, layout...) can affect perception and cognition. In sensory science, with the emerging of new virtual reality (VR) and augmented reality (AR) technologies, the collection and processing of sensory and consumer information is rapidly advancing, moving forward more dynamic aspects of sensory perception, taking account of user-product interactions globally [8,9]. In AR, virtual information and objects are overlaid on the real world. This experience enhances the real world with digital details such as images, text, and animation, in contrast to VR, users are not isolated from the real world [10]. In indoor environment evaluations, VR offers new possibilities for experimental design as well as a functional rapprochement between the laboratory and real life [11]. In fact, with VR, environmental parameters (e.g light, color, furniture...) can be easily manipulated at reasonable costs, allowing to control and guide the user's sensorial experience. Effects of contextual and surrounding stimuli on user's can be easily collected throughout the test, in the form of physiological and behavioral data [12], 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 [13].

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. 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. The main goal of this demo is to show how simulated environments can be used in the evaluation of work-related indoor environments compared to real-world environments. User centric evaluation and sensory analysis in the building sector is in its beginning; this new tool could be of benefit for the building sector, on one hand for methodological facilitation purposes and on the other for cost reductions.

In order to achieve the objectives of this project, a 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 permits 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 unrestricted view of the image in both horizontal and vertical

directions [14]. Research identified a strong correlation between psychological responses and physical environment, as opposed to VR, because of their smaller degree of realism, but stronger degree of sense of presence [15]. The head-mounted display (HDM) allows a fully-immersive system which isolates the user's senses from the external world and gives a higher degree of immersion. It also allows interesting association between photographic technique and VR, making them more interactive and immersive when combined with a HMD.

2 METHODOLOGY

In an objective of validation of the format, 360° photos of workplaces were taken in the building of Halle 6 Ouest of Nantes University. This building can be seen as an example of a "smart building". It was constructed in 2021 in an objective of a collaborative and interdisciplinary space where interactions are at the agenda; The organization of the inter-office spaces has been worked on horizontally and vertically to encourage the development of this ecosystem with multiple users. The upstairs offices are doubly oriented. They face both the exterior and interior facades. They are all distributed through the "engines" extended by their peripheral corridors. These places offer unique perspectives on the entire volume. Two lateral atriums are distributed on either side of the central reception hall, which give access to light on different levels [16]. The shooting was undertaken in two places that serve the purpose of the demo:

- An office room named "le bocal", which offers a more intimate and quiet space, located on the left side of the second floor of the building.
- An open space, named "la mezzanine", which represents a wider and interactive space, located on the last floor at the very center of the building.

The "Insta360Pro" camera was used to take the 360° panoramic photos that were imported via the software Insta360Stitcher and adapted to be seen in a VR headset with the software Unity. To increase embodiment and realism in the 360° scene, two assets were added to the scenes: an office table, where the person has to sit during the experiment and a tablet that will display the instructions, cognitive tests and questionnaires that will be undertaken in both physical and simulated conditions. The following cognitive tests chosen to evaluate subjects performances are typical tasks of office work:

- Rey Test (working memory): A visual presentation of a 15 words list on a screen for 20 seconds, then 20 seconds to restate them orally
- Toulouse-N-back (executive functions): add or subtract multiple of 5 number between 10 and 95, three levels of difficulty (0-back, 1-back, 2-back)
- Anagram word test (higher cognitive functions): A visual presentation of 4 letters, form words with those letters and restate them orally

In order to assess subject's psychological responses to the different environments, three questionnaires [13] are included:

- SMB scale for environmental assessment (7 point likert scale): Rate the environment in terms of pleasantness, complexity,



Figure 1: Schematic representation of the methodology

unity, enclosedness, potency, social status, affection, originality.

- PAD emotional state model (7 point likert scale): Rate your state in terms of pleasure, arousal and dominance.
- SUS Presence questionnaire (7 point likert scale)

These questionnaires were tested in previous research; their validity was assessed. To measure participants non declarative physiological responses and consequently have more insight on user' state, electrodermal activity (EDA), heart rate and eye movement will be measured with respectively portable electrocardiogram (ECG), galvanic skin response electrodes (GSR) and Eye-tracker Tobii Pro.

During the demo, volunteers will be asked to try out the VR immersion and undertake the test. On a screen, people will be able to observe the undergoing test, which will include:

- 1st phase: user "free" observation of the environment
- 2nd phase: user is asked to observe specific cues in the environment and follow instructions
- 3rd phase: user complete the cognitive tests on the tablet
- 4th phase: user complete the questionnaires on the tablet

All through the test physiological data, such as electrodermal activity, heart rate and eye movement will be collected. Concluding the demo some results from collected data during the demonstration will be presented and a discussion will follow.

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