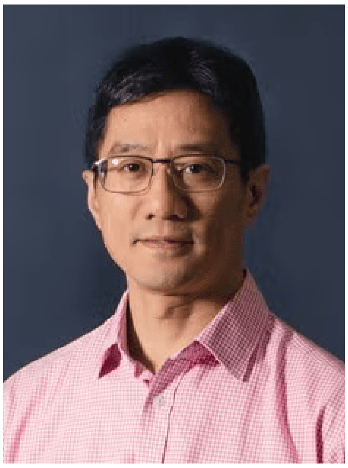
Architecture

Close, but not quite real

Virtual reality can replicate how we see and hear environments, but when it comes to psychological and physiological restoration, the body tells a different story.

Cicadas hum, punctuating an otherwise serene evening. Greenery fills your peripheral vision. You're cosied up in a garden on a university campus, and your shoulders are beginning to drop. Except the garden isn't real — it's a 360-degree projection wrapped around the inside of a six-metre virtual-reality (VR) cylinder, and there are 32 electrodes tapping on your brainwaves.



Associate Professor Eddie Lau Siu-Kit led a team to study the effectiveness of virtual reality in replicating the real world.

This is the experimental setup behind a recently published study led by Associate Professor Eddie Lau Siu-Kit from the Department of Architecture, College of Design and Engineering, National University of Singapore, that tackles a question central to how we research the built environment: when designer and researchers use VR to study how spaces make people feel, how closely does that virtual experience reflect the real world? Can we trust what the data tells us?

The study also reflects a broader research programme spanning three complementary papers: a systematic review, a perception-focused experiment, and a psychological and physiological study. Across the two empirical studies, the team worked with 64 participants and examined environments ranging from a forest and an urban park to campus spaces and a dense retail district. Together, his findings suggest that the answer is neither a simple yes nor a no. VR can be highly persuasive, but its validity depends strongly on how the virtual environment is built and measured.

Seeing is believing. Feeling is another matter

The concept in question is ecological validity — the degree to which laboratory results reflect what happens in the real world. It is especially pertinent to research areas like architecture, urban design and environmental psychology — if a VR experiment shows that a particular soundscape reduces stress or supports restoration, that finding might shape the design of a hospital courtyard, a public park or restorative indoor space.

To test the fidelity of VR in the psychological and physiological study, Assoc Prof Lau's team put 27 participants through every combination — a campus garden rich with birdsong and cicadas, and an indoor rest zone with traffic noise filtering through windows — each experienced in the real world, inside a cylindrical VR environment and through a VR-enabled head-mounted display. Throughout, participants wore monitors that capture brain activity and heart rate, and completed questionnaires on factors from soundscape perception to psychological restorativeness.

"We wanted to go beyond just asking people what they perceived. To ensure VR is a reliable design and research tool for environmental design, it needs to capture the physiological and psychological responses, too. And these are things people can't easily report," explains Assoc Prof Lau.

The body keeps its own score

On perception, VR performed well. Both setups produced audio-visual assessments that closely matched real-world evaluations — participants rated soundscapes, landscapes and overall environments similarly regardless of whether they were physically present or virtually immersed.

That strong perceptual performance was not accidental. Across the wider programme, the team found that ecological validity improved when auralisation was calibrated by about -8 dB, when spatial audio methods such as ambisonics and synthesis replaced monaural reproduction, and when 3D video was used to strengthen visual realism. Virtual walking also appeared to improve ecological validity by giving participants a more natural way to explore the scene.

But the results differed when the team examined psychological restoration — measures of how calming, restorative or compatible an environment felt. Neither VR tool perfectly replicated the actual experience. In some cases, the results flipped entirely: participants rated compatibility — the sense of belonging in a space — differently in VR than in reality, sometimes reversing which site scored higher. The cylindrical VR fared slightly better than the headset, but neither was a clean stand-in.

Two sites in different experimental conditions. (a) Garden in real-world and head-mounted display; (b) Indoor in real-world and head-mounted display; (c) Garden in cylindrical VR; (d) Indoor in cylindrical VR.

Physiologically, the divergence deepened. Heart-rate data from the head-mounted display differed significantly from real-world readings, while the cylindrical setup tracked closer to reality. Brainwave data painted a nuanced picture: both VR tools could approximate how brain activity shifted overall during exposure and how it differed between the left and right hemispheres. But the moment-to-moment fluctuations that real environments produce — the subtle ebb and flow of neural activity — eluded the headset. But the cylinder held up.

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"What surprised us was how much the type of VR setup influenced the physiological results," adds Assoc Prof Lau. "Head-mounted displays are more immersive in some ways, but that immersion doesn't guarantee ecological validity."

What the wind can't carry

Why the gap? The team points to what VR omits. Real environments deliver an explosion of sensory experiences ranging from smell, temperature and humidity to the brush of the wind and the fickle movement of tiny critters. Participant interviews confirmed this: the absence of non-audio-visual sensory cues was noticeable, and it appears to blunt the restorative response. A garden you can see and hear but not feel on your skin is, physiologically speaking, just not the same.

Participants noted that the cylindrical setup couldn't render the sky or the ground beneath their feet — yet it still outperformed the headset on several physiological measures. Room-scale VR, by allowing a more natural body posture and visual field, may avoid some of the physiological artifacts introduced by wearing a device strapped to the face.

"As VR becomes a standard tool for testing biophilic design strategies and urban noise mitigation, knowing where it is trustworthy and where it isn't becomes a practical design concern," adds Assoc Prof Lau.

His team plans to expand the work to include a wider range of environments and additional physiological measures such as skin conductance, respiratory activity and muscle tension. But the broader ambition goes beyond extending the experiments. Through their review work, the researchers have also proposed a framework for studying ecological validity in VR — one that helps future studies think more systematically about parameters, methods and experimental design. They also aim to explore whether different types of settings call for different VR tools altogether. The virtual and the real may never perfectly converge, but the gap, at least, is becoming measurable. ◆