

State of the Art in the Collection of Physiological and Biometric Data in VR Simulations of Nature and Architectural Design in Urban Spaces: Impact on Well-being

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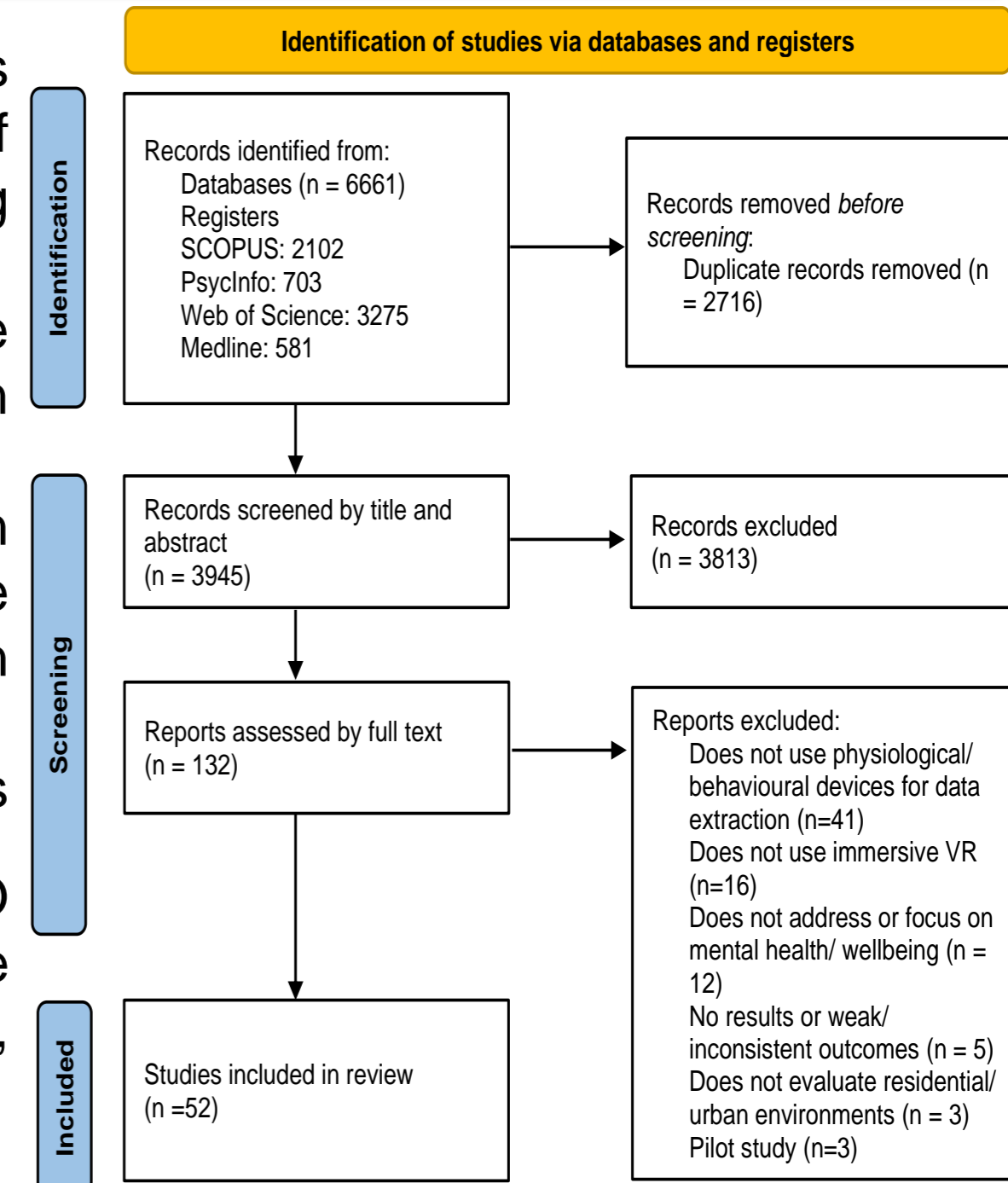
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INTRODUCTION & AIM

- The virtual reality (VR) has opened up new possibilities for studying the relationship between environmental design and human well-being;
- At the same time, monitoring simulation in real time is necessary to better understand human behavior during experimentation, as it allows quantifying data that are often difficult to measure through traditional research methods, often with a qualitative bias;
- This article presents a systematic review (SR) of the evolution and current state of the art of technologies used to collect physiological and biometric data in VR-based studies involving simulations of nature and architectural design in urban Spaces;
- The objective of this SR is to identify contributions from studies involving VR simulation of nature and architectural design in urban environments, analyzing the physiological/biometric devices and complementary data collection instruments used;
- The findings aim to provide technological and methodological insights for future research on the use of VR on the design of urban spaces to improve well-being and restoration.

METHOD

- Potentially eligible articles identified through a review of their titles and abstracts, using Ryyan APP (<https://www.ryyan.ai/>);
- Selected full texts were screened to confirm inclusion in the final review;
- Any disagreements within each pair of reviewers were resolved with the intervention of the third reviewer;
- Use PRISMA 2000 guidelines (<https://www.prisma-statement.org/>);
- Registered in PROSPERO (CRD 42024528802), the international registry for SR, (<https://www.crd.york.ac.uk/prospéro/>).

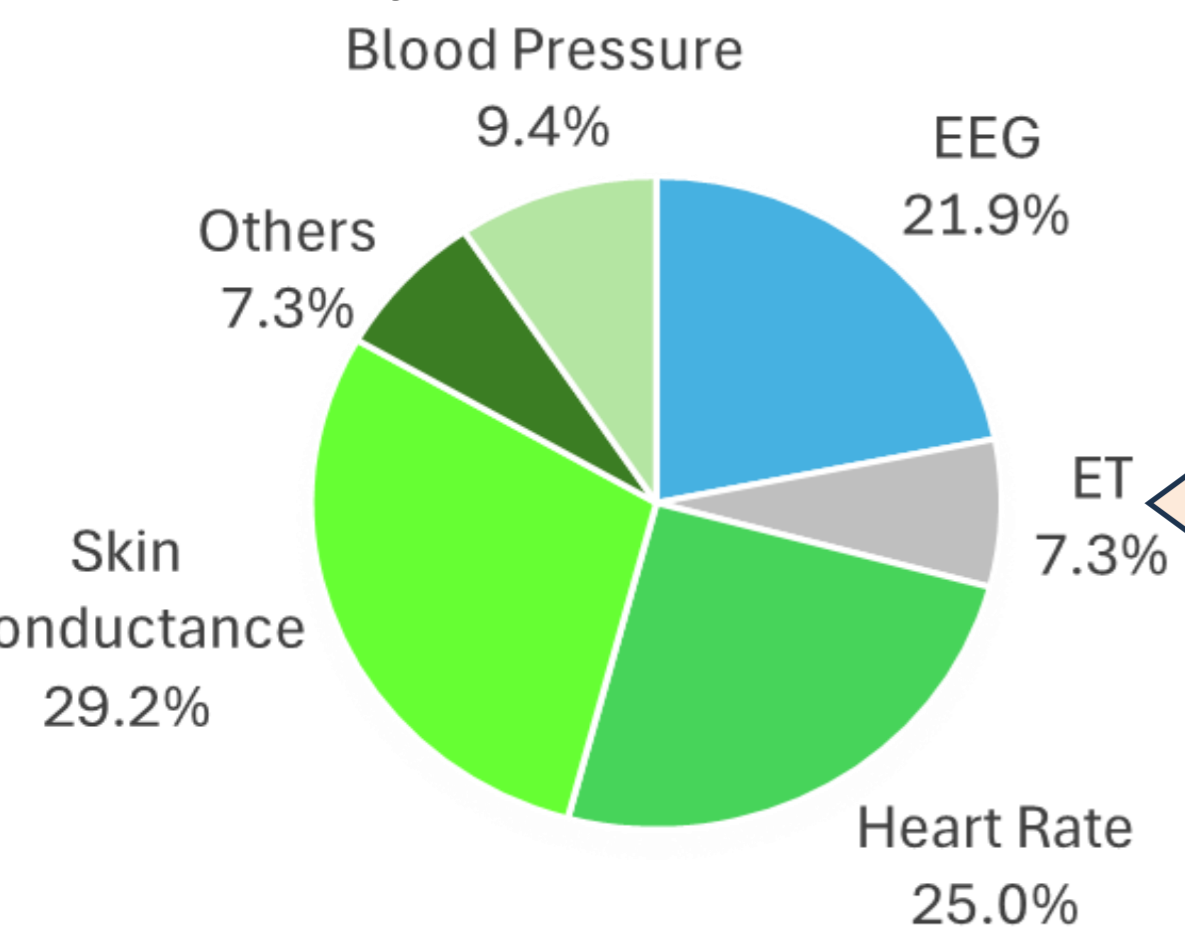


RESULTS

Articles by type(s) of device used

CPD	EPD	BBD
12	24	2
9		
5		

Studies by measurement sensor

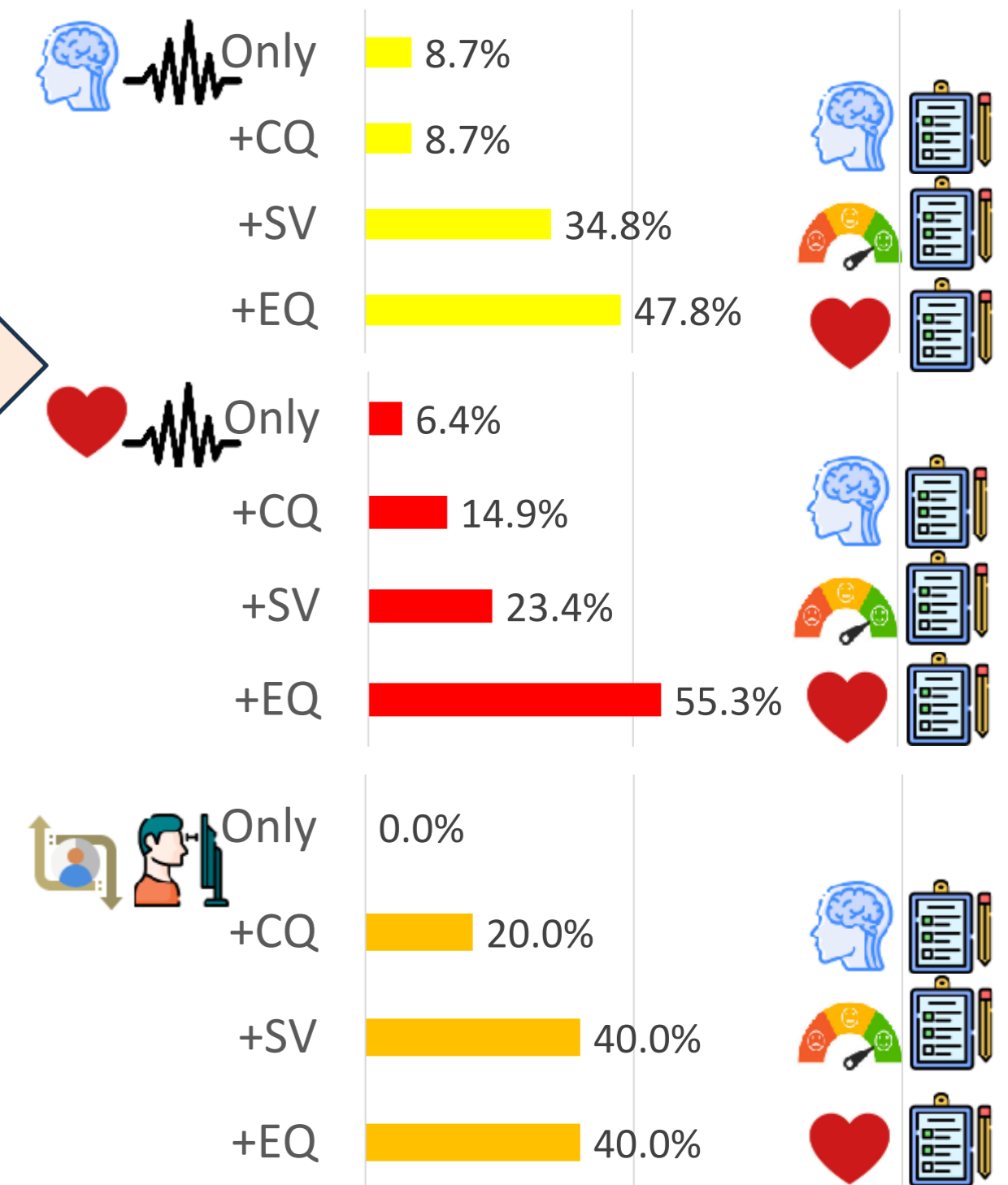


- The devices used were classified as cognitive physiological (CPD), emotional physiological (EPD) and behavioral biometric (BBD);
- Some studies employed 2 or more types of devices. No experiments reported the combination CPD and BBD;

- Cognitive Questionnaires (CQ), Opinion/Personality Surveys (SV) and Emotional Questionnaires (EQ) have been used extensively with the physiological and biometric devices;

- Electroencephalogram (EEG) was the only type of physiological sensor used as a source of cognitive data, varying model (6-128 channels) and 9 diverse brands;
- Eye Tracking (ET), as biometric device for behavioral data, was used when available in the VR headset;
- Approx. 30% of the studies did not report the model and technical details of the physiological devices used;
- Others physiological sensors such as electrocardiogram (ECG), Finger Pulse and Salivary Cortisol were used as source of emotional data;

Experiments combining devices with other data collection instruments



DISCUSSION

- EPD was employed in 38 studies (73%), either alone or combined with other devices, showing the dominance of emotional response analysis. This is largely due to its affordability, less invasive nature, and easily interpretable signals. However, it required additional data sources, as all studies used 2 to 4 sensors, and supplementary questionnaires (94%);
- The lower number of CPD experiments (21) is attributed to their higher cost, complexity (+ variables), and difficulty in VR syncing. Nonetheless, these experiments yielded significant results. About 20% also incorporated EPD, facilitating comparisons between cognitive and emotional responses, with questionnaires being used in over 90% of the studies;
- The only 7 experiments with BBD are related to the fact that it is a newer technology and difficult to integrate, therefore it is only used with the new VR headsets that integrate the ET feature. No joint studies with CPD were identified and all included questionnaires/surveys in the methodology.

CONCLUSIONS

- The 52 selected articles demonstrate the efforts of applying data collection devices and instruments in the search for consistent results in interactive VR experiments investigating nature and architectural design as restorative elements;
- The primary conclusion of this SR suggests that the effects of natural elements and urban architecture on human well-being can be comprehensively investigated using VR. However, this potential can only be fully realized when multiple data sources are employed in a synchronized and complementary manner;
- Since no studies have simultaneously integrated cognitive, behavioral, and psychological variables at the same time, the key challenge for future research is to develop methodologies using available technologies that incorporate all three dimensions to provide more comprehensive results.