http://medpr.imp.lodz.pl/en https://doi.org/10.13075/mp.5893.01633
REVIEW PAPER

A REVIEW OF CONTEMPORARY METHODS OF STUDYING THE EXPERIENCE OF OLDER ADULTS

Magdalena Wąsowicz, Anna Berbesz-Wyrodek

Wrocław University of Science and Technology, Wrocław, Poland
Faculty of Architecture, Department of Architectural and Structural Design

Highlights

- Biofeedback-based methods enable objective assessment of seniors' experience.
- Ecological momentary assessment (EMA) enable objective assessment of seniors' perception.
- Integrating EMA and body sensor networks (BSN) enables innovative research on spatial perception in seniors.
- Neuroscience and biometric sensors enable objective assessment of user experience.
- Applying evidence-based design and BSN supports the design of health-promoting spaces.

Abstract

Understanding user perception and experience is one of the key challenges in cognitive science and architecture. Anticipating user needs at the design stage, particularly those of the primary beneficiaries of an architectural structure or urban space, constitutes a central focus in user experience research. This article explores contemporary methods for studying the experiences of users in architectural environments, in particular, considering seniors. The study reviews the transition from foundational approaches – such as environmental psychology and evidence-based design – to technologically advanced methods incorporating biometric sensors. It highlights the potential of integrating physiological and behavioral data to capture cognitive-emotional responses to architectural spaces. Ultimately, the study advocates for the integration of advanced digital tools with traditional architectural research to create more inclusive, stress-reducing environments that enhance the quality of life for older individuals. The article presents a systematic literature review and analysis of current research on the user experience in architectural spaces. Special attention is given to the application of ecological momentary assessment (EMA) using body sensor networks (BSN), which enables real-time data collection, minimizes memory-related biases from surveys and retrospective interviews, and provides objective measurements of physiological and behavioral parameters, complementing subjective self-reports obtained through traditional methods. As research tools, data visualization techniques were utilized, including VOSviewer, which enables the graphical representation of keyword co-occurrence within leading scientific databases, Web of Science and Scopus. In view of the current development of technology it is possible to conduct EMA studies with older adults using BSN. Conducting such research, however necessitates an interdisciplinary approach, combining neuroscience, cognitive science, and universal design. Ongoing research is essential to refine design practices and create built environments that are inclusive and stress-reducing, ultimately providing an ergonomic and better-adapted architectural space for older adults. Med Pr Work Health Saf. 2025;76(4)

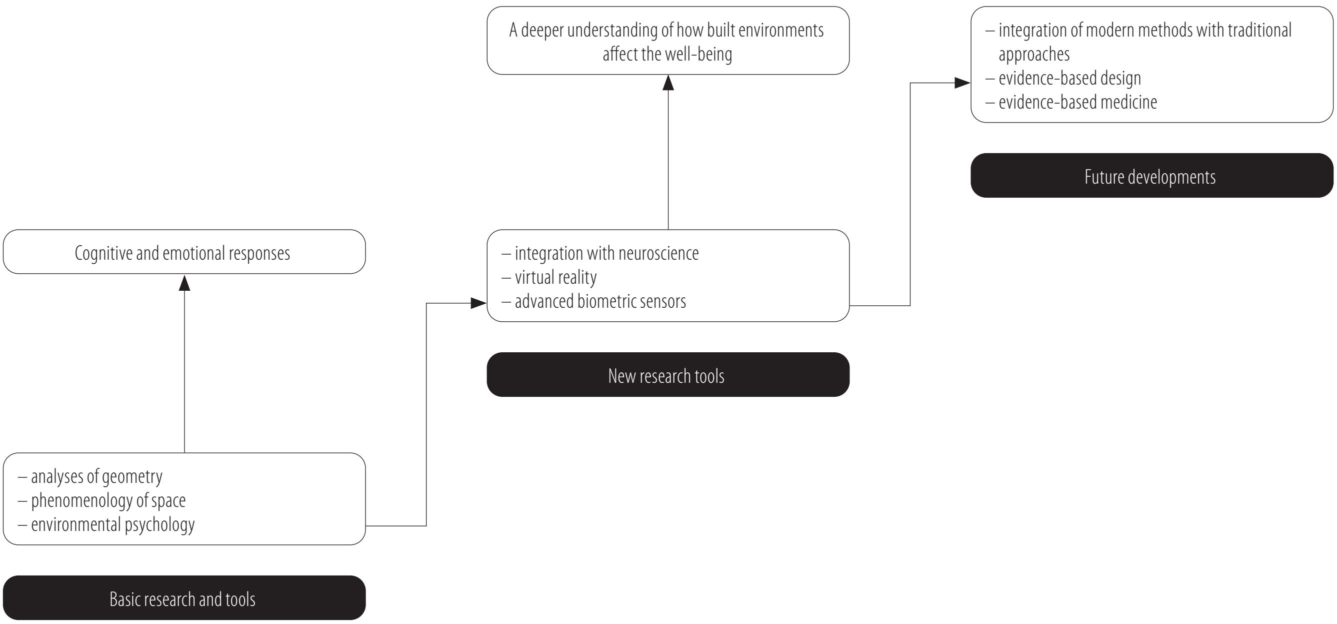
Key words: brain mapping, neuroarchitecture, spatial perception, perception in architecture, body sensor networks, ecological momentary assessment

Corresponding author: Anna Berbesz-Wyrodek, Wrocław University of Science and Technology, Faculty of Architecture, Department of Architectural and Structural Design, Bolesława Prusa 53/55, 50-317 Wrocław, Poland,
e-mail: anna.berbesz-wyrodek@pwr.edu.pl
Received: February 28, 2025, accepted: June 27, 2025

INTRODUCTION

Research on the impact of architecture on human experience has evolved significantly over time (Figure 1). Early research primarily used foundational approaches – such as analyses of geometry, the phenomenology of space and environmental psychology – to examine how basic design elements affect cognitive and emotional responses. These early methods laid the groundwork, revealing the inherent connections between physical spaces and human behavior. One such method is ecological momentary assessment (EMA), a method that assesses individuals' current experiences, behaviors, and moods as they occur in real time and in their natural environment. Ecological momentary assessment captures immediate responses to environmental stimuli as participants interact with their surroundings.

In recent years, technological advances have introduced new research tools, including the integration of neuroscience, virtual reality, and advanced biometric sensors. These innovations enable the objective quantification of physiological and psychological responses, pro-



Based on data from Higuera-Trujillo et al. [1, p. 7].

Figure 1. Research on the impact of architecture on human experience over time

viding deeper insights into how built environments impact user well-being. By combining EMA with modern biometric sensing technologies, researchers can better understand the complex interactions between individuals and their surroundings. Ultimately, the integration of these contemporary methods with traditional approaches has contributed to the emergence of neuroaesthetics – an interdisciplinary field that enhances understanding of user experience in architectural spaces [1].

Thanks to the development of tools available in environmental psychology, an evidence-based design (EBD) approach has evolved, defined as a process of applying empirical research to architectural decision-making [2]. Originating from the medical field as an extension of evidence-based medicine, EBD has been widely used in healthcare environments and has since expanded to various architectural contexts [3].

Studies within this framework have explored the impact of diverse architectural variables on human wellbeing, including ceiling height, presence of vegetation, spatial complexity, illumination, and color. Similarly, access to greenery has been shown to reduce stress and improve emotional well-being. Other environmental factors, such as lighting conditions, influence cognitive performance and mood regulation, with natural light contributing to reduced hospital stays and improved patient recovery. Additionally, spatial complexity and coherence play a crucial role in user perception [3].

Previous research has extensively examined the impact of indoor environmental design on stress levels, particularly in healthcare facilities, educational institutions, and office spaces [4–7]. Studies indicate that specific spatial configurations can contribute to stress by influencing both individual and workplace needs. Key environmental factors, such as access to natural views, lighting conditions, color schemes, and the presence of visual cues or wayfinding elements, have been found to either alleviate or exacerbate stress levels [5–11]. However, modifying built environments post-construction to incorporate such stress-reducing features is often impractical. For instance, research has demonstrated that lighting conditions significantly impact stress and anxiety, with lower luminance levels contributing to heightened stress responses during cognitively demanding tasks [12–14]. Evidence-based design is also used for post occupancy evaluation (POE) of other facilities as well, functionality, efficiency, aesthetics and sustainability are evaluated [15–18].

Evidence-based design in architecture for the elderly focuses on creating environments that enhance safety, well-being, and quality of life. For example, staircase design is one of the relevant subjects within this framework, as it directly affects the risk of falls, one of the most significant safety concerns for older adults. Although staircase design is subject to various building codes, evidence-based studies have shown that optimizing elements such as specified handrail position, dimensions and surface texture, step finishing materials, consistent illumination levels, and the placement of lighting switches can significantly reduce fall risks [19]. Detailed architectural features are suitable for systematic evaluation and improvement based on empirical data. Lighting strategies in senior living environments can mitigate circadian disruption and improve sleep patterns through programmable 24-hour lighting algorithms [20]. The design of care environments should consider layout, sensory aspects, and privacy, with ongoing POEs to adapt to changing needs [21]. For people with dementia in long-term care settings, specific design interventions can positively impact behavior, function, well-being, social abilities, and orientation [22]. These interventions include basic design decisions, environmental attributes, ambience, and environmental information.

Despite the advancements in EBD for elderly-friendly architecture, a significant research gap remains in utilizing body sensor networks (BSN), neuroscience methods, and digital tools to assess the cognitive-emotional impact of architectural spaces on older adults. While existing studies have focused on physical safety, lighting, air quality, and spatial organization, they largely rely on traditional evaluation methods such as surveys and observational studies. The integration of objective, real-time physiological and neurological measurements could provide deeper insights into how architectural features influence stress, comfort, and overall well-being in elderly populations. Emerging technologies, including biometric wearables offer new possibilities for refining design strategies, yet their application in aging-related research remains limited.

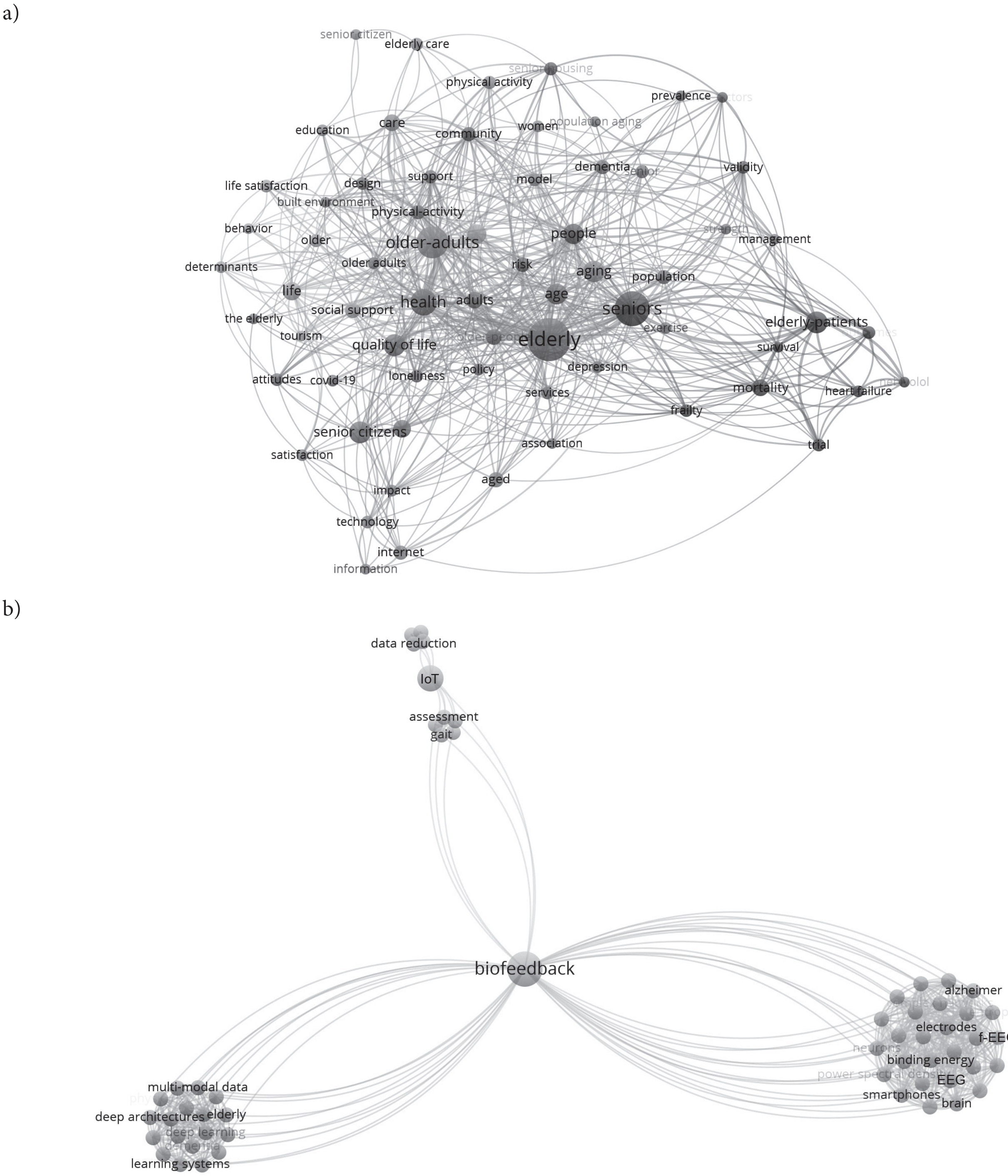
METHODS

The article addresses the challenge of assessing the feasibility of conducting EMA studies with older adults using BSN in the context of current knowledge and advancements in digital technology. The methodology of this study is based on a literature review of current EBD studies on user experience in architecture. This approach aims to identify gaps in existing research on the use of BSN, neuroscience methods, and digital tools for assessing the cognitive-emotional impact of architectural spaces on older adults. Addressing this gap would enhance designers' ability to create adaptable, responsive environments that better support the psychological and physiological needs of older individuals.

Data visualization techniques, including VOSviewer (Leiden University's Centre for Science and Technology Studies, Leiden, The Netherlands), were employed as research tools to graphically map keyword co-occurrence within major scientific databases, Web of Science and Scopus. The article was downloaded in comma-separated values (CSV) format and processed using VOSviewer to visualize and analyze bibliometric trends. The software program VOSviewer is used for bibliometric analysis and visualization, which includes the creation of publication maps, keyword maps, and other visualizations to examine research trends and subject areas. In the initial visual analysis, the relationships between the following keywords were examined: seniors, older adults, architectural design for older individuals, housing, and perception (Figure 2a). The analysis reveals numerous interconnections among these keywords. In the context of the present study, the use of VOSviewer enabled the identification of key research directions concerning the perception of older adults in architectural environments, as well as the detection of niche areas requiring further scholarly exploration. One of the core functionalities of the tool is its ability to analyze the temporal evolution of research topics, allowing for the tracking of shifting academic interests and the identification of emerging trends. VOSviewer also facilitates clear density visualizations, which support the recognition of dominant research themes and marginalized or potentially underexplored topics. While research on the experiences of older adults in architectural environments is being conducted, there is a lack of in-depth studies on user perception utilizing biofeedback-based methods, such as BSN. The visual keyword analysis highlights a research gap in the field of advanced perceptual studies focused on older adults (Figure 2b).

Methods used to assess human physiological and psychological responses

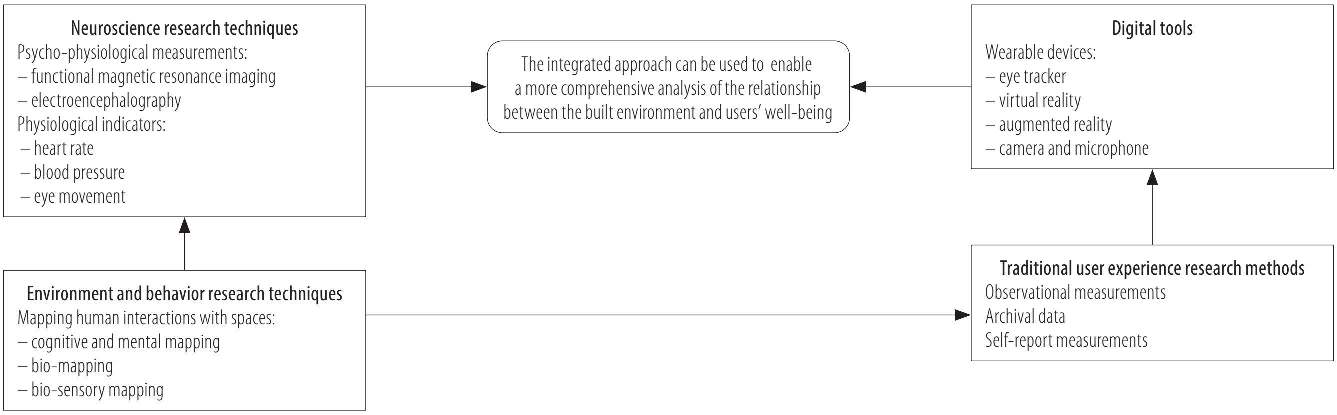
Research into the impact of the built environment on the elderly often uses self-reporting methods, such as verbal feedback, surveys, and visual audits. While these approaches provide valuable insights, they are susceptible to bias stemming from the participants' subjective experiences and emotional states. Individuals may report differently from what they actually feel or perceive, leading to discrepancies between personal perceptions and objective reality. To overcome these limitations, objective research methods are employed to capture an accurate picture of human responses to architectural spaces. These include interviews, walk-throughs, and EMA [23].



EEG – electroencephalogram, f-EEG – fetal electroencephalogram, IoT – Internet of things.

Figure 2. Visual analysis of keywords, conducted for articles from the Web of Science database using the VOSviewer tool: a) in the field of seniors, older adults, architectural design for older individuals, housing, and perception; b) in the field of seniors, older people, biofeedback, and architectural design, February 2025

Additionally, advanced biometric sensors and neuroscience-based methods are increasingly used to complement these qualitative and observational techniques. Biometric measurements, such as monitoring heart rate, skin conductance, and eye movements, offer physiological data that track emotional and stress responses, thus providing an understanding of how individuals engage with and are affected by their environments. Together, these techniques enable an assessment of the relationship between the built environment and well-being, focusing



Based on data from Karakas and Yildiz [23, p. 240].

Figure 3. Research techniques related to the built environment and neuroscience studies

not just on what people think or recall, but on what they actually feel and how they interact with the space in real-time. By integrating both subjective and objective data, research can offer valuable insights for designing environments that enhance comfort, safety, and emotional well-being, particularly for the elderly [23].

Research techniques applied in the study of the user experience in built environment can be categorized into 3 primary domains: environment and behavior research techniques, neuroscience research techniques, and digital tools. Environment and behavior research techniques focus on mapping human interactions with spaces through cognitive and mental mapping, bio-mapping, and bio-sensory mapping. These approaches facilitate the visualization of emotional responses within real-world settings, allowing for a deeper understanding of user experience. Neuroscience research techniques encompass psychophysiological measurements derived from the central and peripheral nervous systems. These include neuroimaging methods such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), as well as physiological indicators like heart rate, electrodermal activity, and pupil response. To ensure the research value of the recorded responses, biometric data is correlated with information about the environmental stimuli that triggered the reaction. Digital tools are used to integrate wearable biometric devices, GPS tracking, and mobile camera systems.

Coupling data from wearable sensors with behavioral information, such as spatial position, movement speed and direction (tracked via GPS), and gaze direction (recorded through eye-tracking), allows researchers to contextualize physiological responses in relation to specific architectural stimuli.

To fully capture the subjective dimension of human experience, these objective measurements should be complemented by qualitative evaluations. This includes the use of structured questionnaires assessing participants' affective states, using established tools such as Likert scales, semantic differentials, or the *Self-Assessment Manikin* [23], which are commonly employed to quantify emotional valence and arousal. Crowdsourcing data from geosocial media and utilizing virtual reality (VR) technologies enhance the analysis of emotional and sensory responses in real-time built environments (Figure 3) [23].

Emotional processes and its evaluation

Human experience is typically evaluated along 2 dimensions: valence and arousal. Valence represents the emotional spectrum from positive to negative states, such as relaxation vs. stress or happiness vs. sadness. Arousal, on the other hand, measures the intensity of the emotional response, indicating how strongly an individual experiences a particular emotion [24–25].

Positive emotions encourage individuals to maintain contact with the situations or objects that triggered them, such as lingering in a pleasant environment. However, prolonged exposure to the same positive stimulus may gradually diminish its impact. In contrast, negative emotions prompt individuals to withdraw from the source of discomfort, though these emotions can persist even after the stimulus has ceased to exert influence.

The intensity of an emotion depends on its impact on an individual's behavior and thought process, varying both between individuals and across different situations. Emotion content shapes responses – anxiety may trigger avoidance, anger can lead to aggression, while joy fosters openness to new experiences.

Table 1. Biometric sensors used in neuroscience for architectural research

Method	Parameter tested
Brain activity	
EEG	brain's electrical signals
fMRI	hemodynamic response of neural activity
MEG	neuro-magnetic activity
PET	neuro-nuclear imaging
Skin conductance	
GSR	skin electrical conductivity reaction
Heart activity	
PPG	HRV dynamics change
electrocardiogram	HRV and HR
Facial muscle reaction	
f-EMG	emotional facial reactions
Eye movement	
eye-tracking	visual focus zones and points of interest

Based on research by Ergan et al. [14].
EEG – electroencephalogram, f-EMG – facial electromyography, fMRI – functional magnetic resonance imaging, GSR – galvanic skin response, HR – heart rate, HRV – heart rate variability, MEG – magnetoencephalography, PET – positron emission tomography, PPG – photoplethysmography.

Emotions consist of 4 key components: physiological arousal, such as increased heart rate or muscle tension; cognitive interpretation, which assigns meaning to emotions within a given context; subjective experience, which varies from person to person; and expression, which manifests through facial expressions, gestures, posture, and vocal changes.

Emotions are a response to stimuli originating, among other things, from the surrounding environment. These stimuli can be classified into several categories, including visual (light, color, contrast, spatial arrangement), auditory (sound intensity, frequency, noise pollution), thermal (temperature, humidity, air movement), olfactory (pleasant and unpleasant scents), tactile (textures, material properties), and social (crowding, territoriality, privacy). Each of these elements interacts with human cognitive and physiological processes, shaping emotional responses and stress levels [26].

Stimuli can arise from numerous sources, making the study of experiential research particularly complex, as it requires correlating emotional data with the stimuli suspected of triggering them. Environmental features influence stimuli related to movement in space, which older individuals may perceive more intensely due to functional and cognitive limitations [26].

The study of Ergan et al. [14] constitutes an example of how physiological data, in combination with spatial localization and exposure time in virtual environments, can be used to identify environmental stressors. In this study, changes in brain activity, skin conductance peaks, and heart rate variability were recorded while participants navigated through different architectural layouts in VR. The data were normalized against baseline conditions and analyzed in relation to participants' movement in VR. An increased number of skin conductance peaks, reduced heart rate variability, and shifts in alpha and beta brain wave activity indicated elevated arousal and mental stress in response to design features in observed environment. Multimodal biometric analysis enables the observation of how momentary physiological states can be linked to specific architectural stimuli, allowing for the identification of stress-inducing environmental characteristics [14].

Body sensor networks

Various modern methods of studying human experience in architectural environments aim to determine the impact of design solutions on human experience using BSN. So far, it has been proven that environmental features affect the human experience in space in a wide range.

A BSN consists of multiple biometric sensing devices worn on the body and wirelessly connected to a central system [27]. This technology allows researchers to capture and analyze physiological data in response to specific events and stimuli. Biometric sensors used in user experience of architecture shown in Table 1. Integrated measurement platforms that use biometric tools such as EEG, galvanic skin response (GSR), eye tracking and photoplethysmogram (PPG) are most commonly used in EBD research.

Various metrics have been proposed to understand the impact of visual stimuli and architectural layouts on human emotional and physiological states [5]. Common measures include heart rate, blood pressure, and startle reflex, which help quantify stress, pain, anxiety, and memory responses [5,28]. A BSN enables researchers to monitor these metrics and correlate them with specific stimuli. Table 2 provides an overview of the commonly used biometric sensors, highlighting their ease of deployment in nonmedical research settings [27].

Among these sensors, EEG records the brain's electrical activity via scalp electrodes. Its noninvasive nature, ease of deployment compared with methods like fMRI, positron emission tomography (PET), or magnetoencephalography (MEG), and high temporal resolution make it an intensive tool for capturing both emotional valence and arousal [29,30]. However, interpreting EEG data is com-

Table 2. Overview of commonly used biometric sensors in neuroscience and architecture

Method	Affective state	Processing effort for data evaluation	Implementation difficulty and invasiveness
EEG	valence or arousal	high	easy/noninvasive
f-EMG	valence or arousal	high	easy/noninvasive
Eye-tracking	valence or arousal	high	easy/noninvasive
fMRI	valence or arousal	high	hard/noninvasive
MEG	valence or arousal	high	hard/noninvasive
PET	valence or arousal	high	hard/invasive
GSR	arousal	medium	easy/noninvasive
PPG	arousal	medium	easy/noninvasive
Electrocardiogram	arousal	high	hard/noninvasive

Based on research by Ergan et al. [14].
EEG – electroencephalogram, f-EMG – facial electromyography, fMRI – functional magnetic resonance imaging, GSR –galvanic skin response, MEG – magnetoencephalography, PET – positron emission tomography, PPG – photoplethysmography.

plex and benefits from complementary data provided by other sensors. The GSR measures skin conductance (a proxy for sweat secretion) and shows a positive correlation with emotional arousal [31,32]. The GSR signal combines tonic activity with phasic responses, necessitating separation of these components to detect stimulus-related changes accurately. Similarly, PPG sensors capture changes in blood flow to reliably derive heart rate variability (HRV), an indicator affected by emotional states under controlled activity levels, though HRV alone does not capture the full spectrum of human experience. Additionally, facial electromyography (f-EMG) and eye tracking provide insights into facial expressions and visual attention, respectively, and are relatively easy to deploy [14].

Consultations with experts in neuroscience, environmental psychology, and biomedical engineering underscore that combining sensors is essential for an understanding of stress and anxiety responses [14].

Modern BSN devices are designed to be noninvasive, ergonomic, and adaptable to research settings. Wearable biofeedback technologies, such as wristbands, eye-tracking and dry EEG enable monitoring of physiological responses. These devices are lightweight, wireless, and designed for long-term wear, minimizing physical discomfort and ensuring natural user interaction with the environment. Their integration with motion tracking and GPS systems allows for synchronization of biometric data with spatial positioning. By reducing the burden on study participants while capturing data, these BSN devices enhance the accuracy and reliability of research.

RESULTS

The feasibility of conducting EMA research with elderly individuals using BSN technology is influenced by multiple factors, including participant recruitment, data quality, technological limitations, and ethical considerations. One of the primary challenges lies in ensuring that participants, who may have varying degrees of physical and cognitive limitations, can comfortably and reliably use wearable biometric devices. Differences in individual psychophysical conditions can introduce variability in sensor data, potentially affecting the accuracy of measurements.

Another factor is the potential bias introduced by environmental familiarity. Elderly individuals who have adapted to obstacles or stressors in their surroundings may develop coping mechanisms, leading to an underestimation of the actual impact of architectural design features. This could distort the validity of findings. To mitigate this, participants must be introduced to unfamiliar environments to assess their immediate and unconditioned reactions to architectural stimuli.

The complexity of data integration and analysis is another challenge. Body sensor networks devices and GPS tracking generate large volumes of multimodal data. An additional complication is that both the inferentiality and complexity of data analysis from different sources vary. Synchronizing time-stamped data from various sources requires advanced data processing methods. Furthermore, the lack of clear guidelines for processing and interpreting EMA data in architectural research presents an additional difficulty. Current methodologies primarily focus on controlled environments, whereas EMA relies on conditions where multiple variables may interfere with stress and well-being assessments.

Correlating biomedical data from different measuring devices and correctly interpreting them is very complicated and requires the cooperation of medical professionals, psychologists and computer scientists who operate the databases of collected data.

Participant recruitment and retention pose further logistical and ethical concerns. Ensuring a sufficiently large and diverse sample that represents different levels of mobility, cognitive function, and socioeconomic backgrounds is essential for obtaining meaningful insights. There remains a risk of high dropout rates if the study is perceived as overly invasive or physically demanding.

Ethical considerations surrounding informed consent and data protection must be addressed. Given the nature of EMA data collection, participants must understand how their physiological and behavioral data will be recorded, stored, and analyzed.

Despite these challenges, advances in digital technology provide opportunities to enhance the feasibility of EMA research with elderly individuals. Improvements in wearable sensor accuracy, real-time data analysis, and AI-driven noise reduction techniques offer promising solutions for addressing data complexity. Moreover, the development of user-friendly interfaces and adaptive technologies designed for older populations can help mitigate barriers related to device usability. Body sensor networks technology has advanced, offering noninvasive and lightweight sensors. Future research should focus on refining data processing methodologies, optimizing recruitment strategies, and establishing standardized protocols for EMA studies in architecture and urban planning.

CONCLUSIONS

In light of an aging population and the increasing number of individuals aged >60 years remaining active in the workforce (particularly in caregiving and other physically and cognitively demanding professions) it is essential to understand how the built environment affects their overall well-being. The research methods discussed in this article offer a valuable foundation for designing work environments that reduce stress, promote health, and support the performance and resilience of older employees. Insights from EBD and EMA methodologies provide valuable tools for architects and urban planners, allowing them to address not only the physical attributes of built environments but also their broader effects on mental and social well-being.

By synthesizing data from multiple sources, researchers can gain an understanding of the relationship between urban environments and human experience. Analysis highlights the potential of BSN techniques in measuring physiological, behavioral, and cognitive responses to environmental stimuli. This requires an interdisciplinary approach that combines neuroscience, cognitive science, and universal design principles to develop effective research methodologies.

Despite technological advancements that have introduced advanced research tools, challenges remain in conducting studies with senior populations. Further research is needed. The application of innovative study methods can ultimately inform design interventions and policies that enhance urban livability and improve the well-being of older adults [33].

AUTHOR CONTRIBUTIONS

Research concept: Magdalena Wąsowicz, Anna Berbesz-Wyrodek
Research methodology: Magdalena Wąsowicz, Anna Berbesz-Wyrodek
Collecting material: Magdalena Wąsowicz
Statistical analysis: Magdalena Wąsowicz, Anna Berbesz-Wyrodek
Interpretation of results: Magdalena Wąsowicz, Anna Berbesz-Wyrodek
References: Magdalena Wąsowicz

REFERENCES

1. Higuera-Trujillo JL, Llinares C, Macagno E. The cognitive-emotional design and study of architectural space: a scoping review of neuroarchitecture and its precursor approaches. Sensors. 2021;21(6):2193. https://doi.org/10.3390/s21062193.
2. Ulrich RS, Berry LL, Quan X, Parish JT. A conceptual framework for the domain of evidence-based design. HERD. 2010;4(1):95–114. https://doi.org/10.1177/193758671000400107.
3. Ergan S, Shi Z, Yu X. Towards quantifying human experience in the built environment: a crowdsourcing based experiment to identify influential architectural design features. J Build Eng. 2018;20:51–59. https://doi.org/10.1016/j.jobe.2018.07.004.
4. Beukeboom CJ, Langeveld D, Tanja-Dijkstra K. Stress-reducing effects of real and artificial nature in a hospital waiting room. J Altern Complement Med. 2012;18(4):329–33. https://doi.org/10.1089/acm.2011.0488.

5. Parsons R, Tassinary LG, Ulrich RS, Hebl MR, Grossman-Alexander M. The view from the road: implications for stress recovery and immunization. J Environ Psychol. 1998; 18(2):113–140. https://doi.org/10.1006/jevp.1998.0086.
6. Rashid M, Zimring C. A review of the empirical literature on the relationships between indoor environment and stress in health care and office settings: problems and prospects of sharing evidence. Environ Behav. 2008;40(2):151–90. https://doi.org/10.1177/0013916507311550.
7. Ulrich RS, Zimring C, Zhu X, DuBose J, Seo HB, Choi YS, et al. A review of the research literature on evidence-based healthcare design. HERD. 2008;1(3):61–125. https://doi.org/10.1177/193758670800100306.
8. Devlin AS, Arneill AB. Health care environments and patient outcomes. Environ Behav. 2003;35(5):665–94. https://doi.org/10.1177/0013916503255102.
9. Heschong L, Oaks F, editors. Windows and Classrooms: A Study of Student Performance and the Indoor Environment [Internet]. Washington: New Buildings Institute; 2003 [cited 2025 Jul 6]. Available from: https://newbuildings.org/resource/windows-and-classrooms-study-student-performance-and-indoor-environment/.
10. Hidayetoglu ML, Yildirim K, Akalin A. The effects of color and light on indoor wayfinding and the evaluation of the perceived environment. J Environ Psychol. 2012;32(1): 50–58. https://doi.org/10.1016/j.jenvp.2011.09.001.
11. Skorupka A. Do you know your way? A mixed-method study on the use of virtual environments in wayfinding research. In: Haq S, Hölscher Ch, Torgrude S, editors. Movement and orientation in built environments: evaluating design rationale and user cognition. Bremen: Universität Bremen; 2008. p. 21–33.
12. Sternberg EM, Wilson MA. Neuroscience and architecture: seeking common ground. Cell. 2006;127(2):239–42. https://doi.org/10.1016/j.cell.2006.10.012
13. Farbstein J, Farling M. Understanding cognitive processes in correctional settings. Workshop Report New Orleans, National Institute of Corrections; 2006.
14. Ergan S, Radwan A, Zou Z, Tseng H, Han X. Quantifying human experience in architectural spaces with integrated virtual reality and body sensor networks. J Comput Civ Eng. 2019;33(2):04018062. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000812.
15. Niezabitowska E. Post-occupancy evaluation: historia powstania i kierunki dalszego rozwoju. Kwart Archit Urban. 2008;53(2):22–36.
16. Joseph A, Quan X, Keller AB, Taylor E, Nanda U, Hua Y. Building a knowledge base for evidence-based healthcare facility design through a post-occupancy evaluation toolkit. Intell Build Int. 2014;6(3):155–69. https://doi.org/10.1080/17508975.2014.903163.
17. Turpin-Brooks S, Viccars G. The development of robust methods of post-occupancy evaluation. Facilities. 2006;24 (5–6):177–96. https://doi.org/10.1108/02632770610665775.
18. Brambilla A, Capolongo S. Healthy and sustainable hospital evaluation – a review of POE tools for hospital assessment in an evidence-based design framework. Buildings. 2019;9(4):76. https://doi.org/10.3390/buildings9040076.
19. Afifi M, Parke B, Al-Hussein M. Evidence-based evaluation of staircase architectural design to reduce the risk of falling for older adults. J Hous Elderly. 2014;28(1):107–132. https://doi.org/10.1080/02763893.2013.858095.
20. White MD, Ancoli-Israel S, Wilson RR. Senior living environments: evidence-based lighting design strategies. HERD. 2013;7(1):60–78. https://doi.org/10.1177/193758671300700106.
21. Barnes S. The Design in Caring Environments Study Group. The design of caring environments and the quality of life of older people. Ageing Soc. 2002;22(6):775–89. https://doi.org/10.1017/S0144686X02008899.
22. Marquardt G, Bueter K, Motzek T. Impact of the design of the built environment on people with dementia: an evidence-based review. HERD. 2014;8(1):127–57. https://doi.org/10.1177/193758671400800111.
23. Karakas T, Yildiz D. Exploring the influence of the built environment on human experience through a neuroscience approach: a systematic review. Front Archit Res. 2020; 9(1):236–47. https://doi.org/10.1016/j.foar.2019.10.005.
24. Chen M, Han J, Guo L, Wang J, Patras I. Identifying valence and arousal levels via connectivity between EEG channels. Proceedings of the International Conference on Affective Computing and Intelligent Interaction (ACII); 2015 Sep; Xi'an, China. p. 63–9. https://doi.org/10.1109/ACII.2015.7344552.
25. Geiser M, Walla P. Objective measures of emotion during virtual walks through urban environments. Appl Sci. 2011; 1(1):1–11. https://doi.org/10.3390/app1010001.
26. Barranco Merino R, Higuera-Trujillo JL, Llinares Millán C. The use of sense of presence in studies on human behavior in virtual environments: a systematic review. Appl Sci. 2023;13(24):13095. https://doi.org/10.3390/app132413095.
27. Ullah S, Higgins H, Braem B, Latre B, Blondia C, Moerman I, et al. A comprehensive survey of wireless body area networks. J Med Syst. 2012;36(3):1065–94. https://doi.org/10.1007/s10916-010-9571-3.
28. Bar M, Aminoff E. Cortical analysis of visual context. Neuron. 2003;38(2):347–58. https://doi.org/10.1016/S0896-6273(03)00167-3.
29. Clemente M, Rodríguez A, Rey B, Alcañiz M. Assessment of the influence of navigation control and screen size on the

sense of presence in virtual reality using EEG. Expert Syst Appl. 2014;41(4):1584–92. https://doi.org/10.1016/j.eswa.2013.08.055.
30. Pham TD, Tran D. Emotion recognition using the Emotiv Epoc device. Proceedings of the 19th International Conference, ICONIP 2012. Springer; 2012; Doha, Qatar. p. 394–399.
31. Villarejo MV, Zapirain BG, Zorrilla AM. A stress sensor based on galvanic skin response (GSR) controlled by ZigBee. Sensors. 2012;12(5):6075–101. https://doi.org/10.3390/s120506075.
32. Benedek M, Kaernbach C. A continuous measure of phasic electrodermal activity. J Neurosci Methods. 2010;190(1):80–91. https://doi.org/10.1016/j.jneumeth.2010.04.028.
33. Giles-Corti B, Vernez-Moudon A, Reis R, Turrell G, Dannenberg AL, Badland H, et al. City planning and population health: a global challenge. Lancet. 2016;388(10062):2912–24. https://doi.org/10.1016/S0140-6736(16)30066-6.

Publisher: Nofer Institute of Occupational Medicine, Łódź, Poland