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Rethinking small vacant lands in urban resilience: Decoding cognitive and emotional responses to cityscapes

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ABSTRACT

Urban sustainability and human well-being are increasingly influenced by the design and presence of green urban areas, which have been linked to fostering positive emotions among citizens. In light of this, this study investigates the transformation of small vacant lands (SVL) into resilient urban green spaces. The study explores the potential value of redesigning SVL into resilient spaces through design strategies. By considering the perceptions and preferences of residents, the research addresses the issues related to vacancy, limited spaces, social stress, and the impact of landscape composition and configuration on visitors' positive emotions. The research aims to evaluate the effectiveness of resilience strategies and to identify the key landscape elements that contribute to transforming SVL into valued small green spaces within the urban fabric. Methods include a comprehensive literature review, a survey, an experiment with EMOTIVE, and analysis using the Interpretative Phenomenological Analysis (IPA) method. The significance of this study lies in integrating field-based methods with EEG data in small-scale landscape contexts, providing a quantifiable measure of engagement with open spaces. This cross-disciplinary approach enhances the understanding of how minor urban landscape modifications can influence human behavior and well-being, especially when resources are limited. The findings provide insights for policy-driven design practices, stimulating design innovation, and offer urban planners effective strategies to refine park patterns, thereby enhancing human well-being and advancing urban sustainability.

1. Introduction

The global trend of rapid urbanization presents significant challenges and opportunities in urban planning and design, notably in the utilization and transformation of small vacant lands (SVL). These areas, often overlooked in broader urban studies, hold potential for enhancing urban resilience and sustainability. This paper focuses on SVL due to their unique characteristics and untapped potential in contributing to urban green infrastructure. Furthermore, mini-parks are increasingly popular as outdoor recreational areas in densely populated cities (Zhou et al., 2021), highlighting a valuable approach to repurposing SVL to enhance urban livability, create a healthy environment and provide recreational spaces.

Rapid urbanization worldwide can result in environmental issues in cities and have significant implications for human well-being and urban sustainability (Wu, 2014; Liu, Ding, et al., 2019; Liu, Xiu, & Song, 2019). The physical spaces we inhabit, such as urban landscapes and natural environments having a direct impact on our behavior (Kong et al., 2022). Thus, enhancing the positive emotions of urban inhabitants has become a fundamental requirement for attaining the United Nations Sustainable Development Goals of "good health and well-being" and "sustainable cities and communities" (UN, 2015). However, there remains a need to objectively determine how these physical contexts affect our emotions (Yeom et al., 2021). One key aspect of evaluating urban landscapes is the assessment of landscape quality, which is essential for maximizing the use of limited space (Kang et al., 2018). Additionally, the preference and perception of green spaces have been shown to be critical determinants of well-being (Liu et al., 2021; Zhou et al., 2023). In this regards, Urban parks play a crucial role in improving visitors' well-being by eliciting positive emotions (Rahnema et al., 2019; Ulrich, 1984), particularly during times of heightened stress such as the COVID-19 pandemic lockdowns (Zhu & Xu, 2021). Furthermore, urban parks can mitigate the negative impacts of the urban environment on residents, such as air pollution, urban heat islands, and noise (Kong et al., 2022).

In response to urban space constraints, the potential of SVL as a green urban development opportunity is increasingly recognized. These spaces, often resulting from urban processes such as demographic shifts,

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economic constraints, and planning deficiencies, present a unique canvas for innovative urban design and resilience strategies.

In the future, cities will face limited urban space and resources. As such, vacant land can be considered an opportunity for green urban development (Lee et al., 2015). The leftover space is an unoccupied, overgrown, or abandoned area within the city (Luo, 2021). A variety of urban processes contribute to vacancy, such as demographic and preference-based residential shifts, suburban expansion, the former purpose or function of the space ceased, and de-industrialization (Kremer et al., 2013). Additionally, economic constraints, such as the lack of public funding (Lee et al., 2018), alongside deficiencies in urban and district planning, particularly with regard to the integration of open green spaces, further exacerbate the prevalence of vacant urban areas. Moreover, a scarcity of studies examining how organizations engage residents and how different engagement modes relate to their effectiveness further complicates efforts to revitalize these spaces (Rupp et al., 2022).

Vacancy projects require innovative design procedures, combination of all criteria and multiple lenses (Naghibi et al., 2020) due to inefficient resources and low budgets but also unspecified time frames (Lokman, 2017). Furthermore, the built environment in urban areas often features multi-decade or even centuries-long life cycles. Recognizing both the tangible and intangible value of these constructed assets, such as infrastructure and buildings, is crucial to the functioning of society. These elements not only support daily urban operations but also play a pivotal role in enhancing urban resilience. In particular, integrating green spaces within urban planning is essential for reducing vulnerability to environmental and social disruptions. Green spaces contribute to resilience by providing critical ecosystem services (Newell et al., 2022), mitigating urban heat island effects (Aram et al., 2019), enhancing flood control (Junqueira et al., 2022), and offering recreational areas that support community well-being (Mukherjee & Takara, 2018), and social cohesion (Kronenberg et al., 2020). The strategic inclusion of green areas in the urban fabric is vital for sustaining long-term environmental stability and reducing the impact of potential urban crises. Thus, the interest in the resilience of constructed assets is growing regard to natural/man-made disasters (Rezvani et al., 2021). There is no city that is completely free from unforeseen risks or disasters, but it is possible to make it slightly more resistant to destruction (Büyüközkan et al., 2022). Urban resilience is strongly linked with policymaking and strategies. It is a multidisciplinary concept that includes physical, infrastructural, environmental, economic-social (Tarek & Ouf, 2021), political-regulatory, and organizational aspects (Rezvani et al., 2021). As a result of resilience, cities can develop capacity against possible future shocks and protect their social structure, economies (ARUP, 2014), ecological (Childers et al., 2019; Bănică et al., 2020), technical systems (Zhu et al., 2020), and infrastructures (Vargas-Hernández & Zdunek-Wielgołaska, 2020), even in pandemics disasters (AbouKorin et al., 2021; Banai, 2020; Khatibi et al., 2021). In addition to increasing social progress, urbanization also contributes to deteriorating the living environment in a complex and irreversible way, from a local to a global scale (Liu, Ding, et al., 2019; Liu, Xiu, & Song, 2019). Considering that most of the world's population now lives in cities and this situation will follow a growing trend in the future, focusing on the resilience (Khatibi et al., 2021) and sustainability of cities should be given priority (Ahern, 2013; Sharifi et al., 2017; Zeng et al., 2022).

Moreover, cities face the challenge of rapid urbanization and climate change at the same time. Hence, inspirations derived from the holistic and systematic thinking of social-ecological systems are vital for cities to transition toward livability and sustainability (Grafakos et al., 2016; Kim et al., 2020). Urban systems are more sustainable when social and ecological concerns are integrated (Anderies, 2014) instead of overemphasizing one and neglecting the other. Additionally, social-ecological systems are more concerned with the capacity for adaptation and transformation, which is significantly influenced by ecosystem services (Liu, Ding, et al., 2019; Liu, Xiu, & Song, 2019).

Resiliency is the ability of systems to persist, absorb, and recover from the effects of threats and adversities in a timely and resourceful manner (Davoudi et al., 2012) It was Holling (1973), who introduced the city concept of resilience. There has been an increased focus on urban resilience in recent decades across multiple disciplines (Collier et al., 2013; Nunes et al., 2019). With the introduction of this concept to the urban system, which is considered a complex adaptive system, a broader implication of resilience is created (Davoudi et al., 2012). Socio-ecological perspectives that emphasize the dynamic interactions between social and ecological systems across multiple temporal and spatial scales are widely considered essential to building adaptive capacity and adaptability (Meerow et al., 2016; Quigley et al., 2018). The integrative and vague essence of urban resilience makes it a malleable concept, which is beneficial from multiple perspectives for the evolution to a desirable development trajectory by embracing the ability to change as flexibly as possible over time (Spaans & Waterhout, 2017).

It is important to conduct studies involving the conceptual approach, and many of these studies propose resilience frameworks or tools for cities (Pickett et al., 2004). Tabibian and Movahed (2016) presented the urban resilience frameworks and suggested strategies for the development of cities. Yaman Galantini and Tezer (2018) proposed a hypothetical framework to address resilience in urban planning. Lak et al. (2020) have proposed a multidimensional framework for resilient urban design, and Wardekker et al. (2020) have developed a resilience diagnostic tool for urban resilience.

The critical role of urban green spaces in enhancing urban resilience, particularly in adapting to climate changes, is increasingly recognized (Muluneh & Worku, 2022; Wong et al., 2024). Green areas are pivotal not only for their ecological benefits but also for improving the microclimate, enhancing well-being (Reyes-Riveros et al., 2021) and reducing violent crime in urban environments (Burley, 2018). Research underscores 'the greener the better' (Weeland et al., 2019) principle for urban sustainability, and human well-being (Bolanis et al., 2023; Mueller & Flouri, 2021).

Urban green spaces are inadequately researched for their socio-ecological resilience, and adapting to climate change cities beyond just their presence or size (Ha et al., 2022). Only a few studies have investigated the association between design strategies and compositional and configurational aspects of small green spaces (Naghibi et al., 2024). Since the types and distribution of green space contribute to the character of the visual landscape that humans perceive (Chmielewski et al., 2020; Lee et al., 2008) and influence usage patterns of those spaces (Zhang et al., 2017), studies investigating the relationship between landscape pattern and preferences could help to inform future landscape planning and urban design. Accordingly, since the types and distribution of green spaces affect how humans perceive landscapes (Chmielewski et al., 2020; Lee et al., 2008) and how they use those spaces (Zhang et al., 2017), study the relationship between landscape patterns and preferences can be helpful for landscape planning and design in the future (Ha et al., 2022).

This study aims to evaluate resilience design strategies and landscape elements to transform leftover sites into small green spaces while considering the perceptions and preferences of residents. Specifically, the main questions of this study are (1) to identify how resilience design strategies can assist in designing leftover spaces according to the perceptions and preferences of residents and (2) to investigate the landscape elements that contribute to creating more preferred spaces. Moreover, this research will explore how these transformed green spaces can significantly contribute to adapting to climate changes by enhancing urban resilience, and supporting sustainable urban environments.

By integrating a detailed review of urban design theories and examining the practical application of resilience strategies in SVL, this paper enriches the discourse on urban sustainability and resilience within the landscape scale. Despite many studies highlighting the positive impacts of nature contact on urban residents and resiliency, little attention has been paid to design strategies to promote socio-ecological resilience and compare different types. Furthermore, recognizing the key role of urban green areas in adapting to climate change is crucial. Urban green spaces not only enhance the microclimate (Sodoudi et al., 2018; Sun et al., 2023) and air quality (Ai et al., 2023) but also improve the overall quality of life (Dimitrova & Dzhambov, 2017) and support biodiversity (Miao et al., 2023). The strategic integration of these areas is essential for enhancing city resilience against climate variability and extreme weather conditions.

According to this study, the process includes the following: (a) The Literature Review focuses on finding design strategies and landscape elements based on socio-ecological resilience, (b) A Case Study and Methodology introduces the context, explains chosen methods, data collection instruments, and demographics of respondents. (c) The future prototypes of leftover spaces have been presented to be evaluated. (d) A classification accuracy experiment was conducted using a support vector machine (SVM) classifier, (e) Analysis of the data and findings are discussed, (f) The results and implications of the main questions are presented. In the light of resiliency, this study investigates the design strategies and landscape elements of redesigning vacant lands creatively and in accordance with users' preferences and perceptions. Therefore, understanding preferences and perception of leftover spaces leads to more appropriate resilience strategies.

2. Literature review

2.1. User preferences and perceptions

The study of user preferences and perceptions has evolved significantly, contributing extensively to urban planning and landscape architecture. This evolution is particularly important in the context of rapidly changing urban environments where SVL play a crucial role. The empirical assessment of landscape experiences is crucial in understanding the preferences, perceptions, and expectations of users (Batista e Silva et al., 2013, Lis et al., 2022). This body of research has historically pivoted around both rational and emotional criteria in evaluating landscapes, providing a rich tapestry of data that underscores the human-environment interaction. This study builds on these foundational insights by applying them specifically to SVL, exploring how these underutilized spaces can be transformed into valued urban assets.

The overall landscape experience leads to an evaluation of preferences and values that are based on both rational and emotional criteria (Yuan et al., 2023), consciously and subconsciously. This experience encompasses a multitude of landscape features, frequently connecting these articulated values and user preferences to the aesthetic quality of the landscape. In the conservation of landscapes, there is an increasing demand for the systematic description of these qualities and the formulation of (quantifiable) indices for use in scenario modeling and policy assessment. Additionally, there is a growing need to understand how preferences correlate with landscape features (Lis et al., 2022). These approaches have developed since the 1970s with the expansion of scientific research in the description and mapping of scenic qualities, visual typologies, and landscape preferences. This quantitative shift represents a significant innovation in our approach, allowing for more precise scenario modeling and policy assessment. These indices are particularly relevant in the context of SVL where their potential for urban aesthetic and functional enhancement is significant yet underexplored.

The need to understand how preferences correlate with landscape features has led to the development of various quantitative indices. These tools are crucial for advancing landscape architecture into more systematic and scientifically-grounded practices (Lis et al., 2022). This study extends these methodologies by focusing on SVL, which have been relatively underexplored despite their potential to significantly impact urban aesthetic and functional qualities.

Two research paradigms have been presented in this area: The first aims at objectively identifying the physical characteristics of the landscape that may be linked to specific preferences. The first approach is landscape-centric, while the second focuses on the observer (Sevenant, 2010). This research refers to Ulrich's model (Fig. 1) to concurrently study user perception and preferences:

In addition to a preferences questionnaire, this study employs EMOTIV as a tool to complement surveys or expert opinions in landscape evaluation (M. Kim et al., 2019). Recent studies utilizing neuroimaging methods in environmental psychology have shown that different types of urban environments engage distinct patterns of brain activity (Tilley et al., 2017). The inclusion of neurophysiological tools such as EEG in studying urban spaces provides a novel lens through which to assess the impact of aesthetic and functional changes, particularly in SVL.

Existing studies, using EEG, have explored how individuals perceive various environments. These studies mainly compare natural landscapes with built environments (Chang et al., 2008; Roe et al., 2013; Tilley et al., 2017). For instance, Roe et al. (2013) investigated how the brain engages with natural environments as opposed to urban settings. Natural landscapes provoke less excitability than urban scenes. Tilley et al. (2017) measured levels of arousal, engagement, and frustration using EEG depending on specific urban and natural species (eight environmental types) and provided a detailed design concept. This finding underscores the need for a nuanced understanding of aesthetic atmospheres in urban design, particularly as it applies to SVL, where such insights can lead to significant enhancements in urban quality of life.

In general, brain activity can be divided into four types: Delta (<4 Hz), which has slow brain waves with long wavelengths and occurs during the deepest meditation and dreamless sleep. Theta (4–7 Hz) often occurs during light sleep or intense relaxation. Alpha (8–13 Hz) prevails in the stream of quiet thought and in some states of meditation. And Beta (14 to 30 Hz), which is predominant in our normal state of wakefulness when attentive (Elsadek et al., 2020).

2.2. Theoretical frameworks and research progress

2.2.1. Design strategies for socio-ecological resilience

The literature points toward a multifaceted approach where urban design is both a response to and a proactive measure against socio-ecological challenges. Through flexibility, diversity, water conservation, active and connected spaces, accessible environments, and efficient and redundant designs (Naghibi et al., 2022), urban areas can become

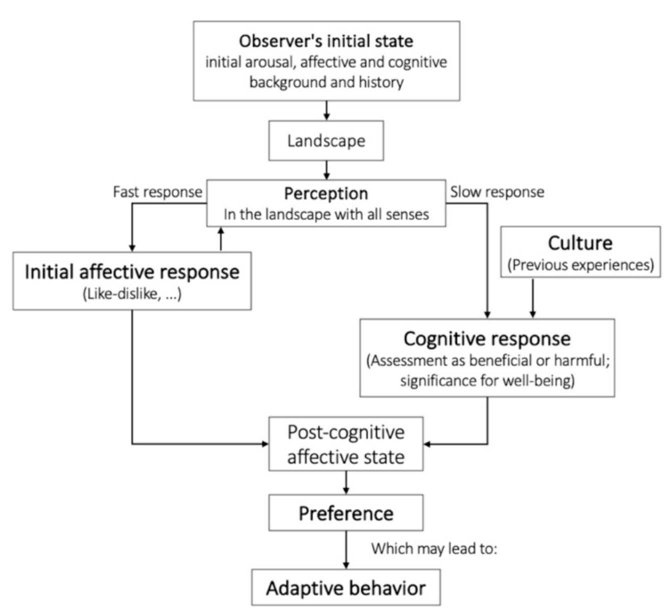

Fig. 1. Ulrich's model for landscape preferences (Ulrich, 1983).

more resilient (Table 1). Implementing urban resilience strategies results in various additional benefits, such as climate change adaptation and mitigation, enhanced pandemic prevention and response, improved human health and well-being, and greater justice (Sharifi, 2023). This synthesis of research underscores the need for an integrated design philosophy that accounts for both human and ecological well-being.

2.2.2. Flexibility in urban environments

The concept of flexibility within urban design is pivotal to socio-ecological resilience. Folke (2006) and Plieninger and Bieling (2010) discuss the importance of dynamic landscapes that can adjust to ecological and social changes over time. Adger (2010) and Davoudi et al. (2012) extend this discussion by emphasizing adaptability to accommodate future uncertainties, allowing urban areas to respond dynamically to both long-term shifts and immediate crises (S1, S2).

2.2.3. Biodiversity and ecological diversity

Diversity in ecological systems contributes to the resilience of urban areas. Laboy and Fannon (2016) suggest that incorporating a variety of native, near native, and non-native species can enhance the robustness of urban ecosystems (S3). Mader et al. (2011) assert the significance of having at least eight different species in urban designs, which can contribute to biodiversity and ecological balance (S4).

2.2.4. Water sensitive urban design

Water features and management are essential components of resilient urban design. Mooney (2020) illustrates how water features like mist or fountains (S6) add to the aesthetic and microclimatic regulation of urban spaces. Additionally, water features tend to offer an ideal restorative experience, and artistic landscape components with significant aesthetic value are crucial for enhancing the health-promoting effects of restorative environments (Deng et al., 2020). Furthermore, Steeneveld et al. (2014) present shading and ventilation strategies as means for natural cooling, emphasizing the role of water in regulating urban temperatures and enhancing human comfort (S7).

As mist cooling gains popularity for urban overheating countermeasures, and streetscaping, assessing its effectiveness alongside other urban microclimatic phenomena is crucial. According to Di Giuseppe et al. (2021), dry mist systems may play a crucial role in combating urban overheating at the local scale (S8). Overall, mist cooling is a high-impact local-scale urban overheating countermeasure. Its effectiveness can be enhanced by strategically placing multiple small-scale installations in city hot spots and proximity to vulnerable populations such as the elderly and low-income groups (Ulpiani et al., 2020).

Table 1
Design strategies for socio-ecological resilience.

Variables		Design strategies	Code	References
Flexibility		Dynamic landscape	S1	(Folke, 2006; Plieninger & Bieling, 2010; Adger, 2010; Davoudi et al., 2012)
		Adaptability	S2	(Laboy & Fannon, 2016)
Diversity	Diversity	Native, near-native, non-native	S3	(Mooney, 2020)
		At list eight different species	S4	(Mader & Berghöfer, 2011)
		Diverse shape, color, size	S5	(Mooney, 2020)
	Water	Fond with water mist or fountain	S6	(Adibi et al., 2005; Moqdami, 2001)
		Cooling based on shading	S7	(Steeneveld et al., 2014)
		Ventilation, evaporation	S8	(Dimoudi & Nikolopoulou, 2003; Cortesão et al., 2019)
Activity		Walking	S9	(Fields, 2005; Loukaitou-sideris, 1996)
		Social Activity	S10	(Ling et al., 2007)
Connectivity		Connecting to all scale	S11	(Permato, 2014)
Accessibility		Openness	S12	(Franck & Paxson, 2007)
		Physical accessibility to all users	S13	(Addas, 2015)
		Accessibility to natural light and fresh air	S14	(Ridzqo & Defaix, 2019)
Efficiency		Smaller elements	S15	(Salat & Bourdic, 2011)
Redundancy		Multiple components or pathways	S16	(Ahern, 2011; Anderies, 2014; Feliciotti et al., 2016)
		Functional redundancy	S17	(Afriyanie et al., 2018)
		Minimal intervention	S18	(Allan & Bryant, 2012)

2.2.5. Promoting urban activity and connectivity

Active design strategies that encourage walking (S9) and social interaction (S10) foster a vibrant and resilient community. Fields (2005) and Loukaitou-Sideris (1996) demonstrate that walkability is associated with better health outcomes and more resilient social structures. Similarly, Ling et al. (2007) and Permato (2014) discuss how connectivity at all scales, from local to city-wide, is crucial for socio-ecological resilience (S11).

2.2.6. Accessibility for inclusive urban spaces

The concept of accessibility is broadened in Franck and Paxson (2007) to include not only physical access but also openness and availability of spaces to all users (S12). Addas (2015) reinforces this by exploring how access to natural light and fresh air contributes to a healthier urban environment (S13). Nordh et al. (2024) further extends this concept by demonstrating that the more satisfied people were with their access to green spaces and safety outdoors in the evenings and nights, the more satisfied they were with their living environments.

2.2.7. Efficiency and redundancy for resilience

Efficiency in the use of urban spaces (S15) and the integration of redundancy in the form of multiple components or pathways (S16) are advocated by Salat and Bourdic (2011), Ahern (2011), and Martin-Breen and Marty Anderies (2011) as strategies to absorb shocks and stresses. This is supported by Feliciotti et al. (2016), who discuss the role of functional redundancy in ensuring continuity when individual elements fail (S17).

2.2.8. Minimal intervention for sustainability

Allan and Bryant (2012) propose that minimal intervention approaches (S18) are a key to sustainable urban development. By reducing the ecological footprint while maintaining functionality, such strategies align with the broader goals of socio-ecological resilience

2.3. Landscape elements for socio-ecological resilience

In the face of escalating environmental challenges and the need for sustainable urban development, the concept of socio-ecological resilience has become a cornerstone in landscape architecture and urban planning. This section examines the landscape components that contribute to the robustness and adaptability of urban environments. This section delves into the dynamic interplay between natural and constructed elements within urban landscapes, exploring how vegetation, water features, topography, built structures, and garden facilities collectively influence ecological sustainability and social well-being. Drawing on seminal works in the field (Mahmoudi, 2006; Pakzad, 2007; Nordh et al., 2009), this examination underscores the importance of thoughtful design and strategic integration of landscape elements, asserting that resilient urban spaces are those that embrace diversity, flexibility, and a deep-rooted connection between people and their environment (Table 2).

2.3.1. Vegetation as a core element of resilience

Vegetation is a foundational aspect of socio-ecological resilience in urban landscapes, playing a critical role in defining the urban form and function (Pakzad, 2007). Trees (E1), bushes (E2), flowers (E3), and ground cover (E4) serve multiple functions from enhancing biodiversity to mitigating urban heat island effects (Nordh et al., 2009). These green elements, in their varied forms and colors, contribute significantly to the aesthetics and ecological dynamics of urban spaces (Mahmoudi, 2006), acting as green paths and spots that enrich the environmental fabric (Deng et al., 2020).

2.3.2. Water features in resilient design

Water features are recognized for their capacity to create microclimates and contribute to the psychological well-being of urban populations (Nordh et al., 2009). Static water elements (E5) and dynamic components (E6) add movement, sound, and a sensory richness that enhances the spatial experience, aligning with the qualities valued in urban furniture (Pakzad, 2007), and ornamental fountains (Bahriny & Bell, 2021).

2.3.3. Topography's role in urban landscapes

Topography, articulated through elements like ladders (E7) and gentle slopes (E8), is essential in managing environmental elements such as water flow, and it plays a role in how urban spaces are perceived and utilized (Pakzad, 2007). It impacts the ground component of the urban landscape, which includes the sidewalks, roadways, and condition of the land (Mahmoudi, 2006). The topographic variation contributes to the resilience by adding complexity and diversity to urban spaces, supporting biodiversity, and offering different vantage points and experiences (Deng et al., 2020).

2.3.4. Built structures for social and environmental benefits

Structures like kiosks (E9), pavilions (E10), and cafés (E11) are integral to urban landscapes as forms of urban furniture that meet user needs, fostering social interaction and community engagement (Pakzad, 2007). Similarly, shade structures (E12) provide shelter and comfort, essential for encouraging the utilization of outdoor spaces (Mahmoudi, 2006), and offer places to sit and relax, enhancing user comfort and sociability (Bahriny & Bell, 2021).

Table 2
Landscape components and landscape elements.

Landscape components	Landscape elements	Code
Plants	Tree	E1
	Bush	E2
	Flower	E3
	Cover	E4
Water feature	Static	E5
	Dynamic	E6
Topography	ladder	E7
	gentle slope	E8
Landscape structure	Kiosk	E9
	pavilion	E10
	Cafe´	E11
	Shade Structure	E12
Roads & Pavements	Paved Walkway	E13
	Pavement part of the way	E14
	Gravel walkway	E15
Garden facilities	Stone	E16
	Garden lamp	E17
	Bench	E18
	Sculpture	E19

Adopted from Nordh et al. (2009), Nordh et al. (2011), Deng et al. (2020) and Bahriny and Bell (2021).

2.3.5. Roads and pavements as connective tissue

The roads and pavements play a pivotal role in the connectivity and movement within urban landscapes, influencing the physical form and function of urban spaces (Mahmoudi, 2006; Pakzad, 2007). Paved walkways (E13) and gravel pathways (E15) not only facilitate movement but also incorporate material and aesthetic considerations and reflect design decisions that impact user experiences and landscape resilience (Mahmoudi, 2006; Deng et al., 2020).

2.3.6. Garden facilities for human-nature interaction

Elements such as stones (E16), garden lamps (E17), benches (E18), and sculptures (E19) are considered urban furniture that enhances the safety, comfort, or beauty of the environment (Pakzad, 2007). These features support the various uses of gardens and parks, extending accessibility and enjoyment into the evening hours, thus contributing to the socio-ecological resilience of urban landscapes (Mahmoudi, 2006; Bahriny & Bell, 2021).

2.3.7. Integration of elements for resilience

The integration of these diverse landscape elements, from vegetation to build structures and garden facilities, aligns with the components that make up the physical form of urban spaces (Pakzad, 2007). This coherent approach ensures that urban landscapes can support ecological functions and meet social needs, embodying the interplay between the hardscape and green elements as vital for the development of resilient urban spaces (Nordh et al., 2009), and reinforcing the importance of beautiful landscape design as an element of urban resilience (Bahriny & Bell, 2021; Deng et al., 2020).

To understand how each of these design strategies and elements contributes to the overall resilience of the landscape, this study conducted a survey.

3. Methodology

This study used a combination of methods to examine the emotional responses of residents to different design scenarios. The combination of EMOTIVE and IPA proved to be a powerful tool in identifying the most important design features to residents and their emotional responses to those features. This section outlines the contextual framework of the study, introduces the methodology procedure, the case study and its context, explains the chosen methods, describes the data collection instruments used, and provides the demographics of the respondents.

3.1. Methodology procedure

As illustrated in Fig. 2, the methodology of the research paper is structured into five sequential steps. The first step involves conducting interviews with experts to determine the most relevant landscape components. This is followed by a comprehensive literature review to identify key design strategies and landscape elements. The third step is the creation of a design prototype, featuring sixteen different scenes for analysis. In the fourth step, the experimental procedure, EEG data are collected and analyzed using an assessment matrix. Finally, the fifth step is the analysis phase, where EEG results are interpreted using Importance-Performance Analysis (IPA). Furthermore, the experimental procedure is detailed through sub-steps such as a pre-test, the experiment itself, and a post-test.

3.2. Site field

Since Tehran became the capital city over two centuries ago, the city's demography and urbanization have changed dramatically. A metropolitan area of 15 million people surrounds Tehran, which has a population of 8.7 million. Rapid urban growth has frequently created voids in the urban fabric caused by unequal growth. Land plots are occasionally left undeveloped due to a lack of resources, the absence of

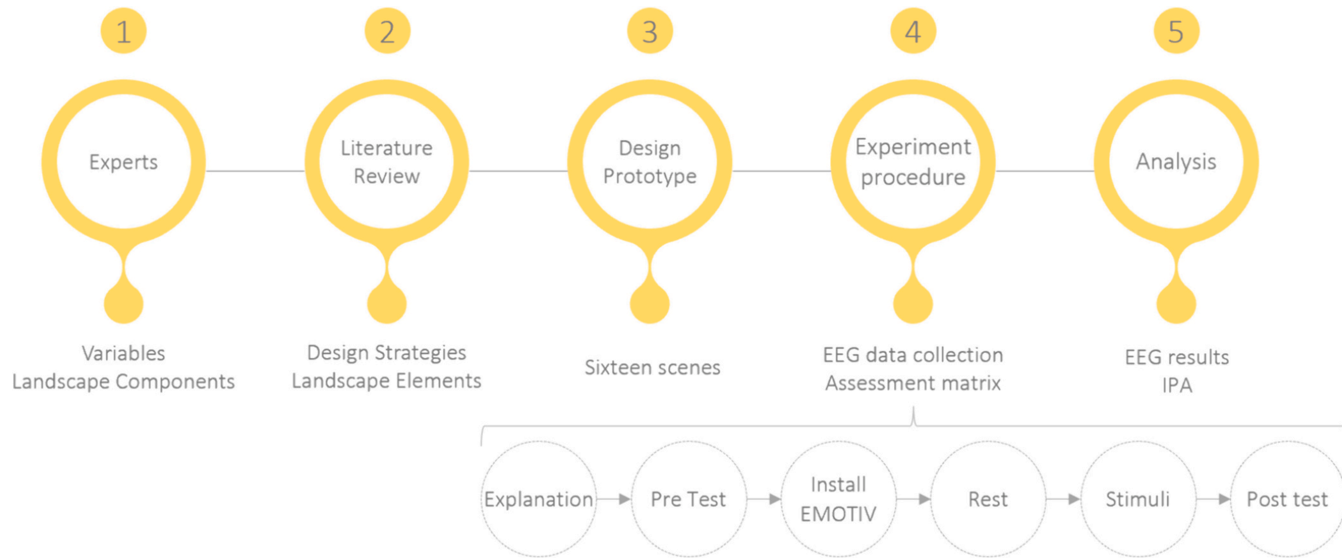

Fig. 2. Methodology procedure.

owners, or the site's unique development challenges, such as problematic terrain or form. Taking up the case of Tehran City, Iran, this study examines the potential of leftover spaces in two districts of this metropolitan region. Tehran metropolitan area has faced limited and high-density challenges. This study identifies vacant parcels for potential greening, focusing on public land lacking buildings, close to the neighborhoods, and believed to be unutilized by neighbours. The area that is selected for this field includes spaces in the north of Tehran (Fig. 3).

This study selected cases based on criteria that included the presence of vacant land, proximity to neighborhoods, residents' perceptions of spaces being leftover, and uncertain usage. The site selection process entailed interviews with citizens and experts to collect valuable insights. As shown in Table 3, the chosen case studies covered a range of spaces such as marginal areas, in-between spaces, under-bridge spaces, and vacant lots. These case studies were considered appropriate for thorough examination and analysis within the research's framework.

3.3. Scenario development and experimentation procedure

In addressing the complexities of leftover spaces in Tehran, this study explores the perceptual and emotional responses of participants. After categorically selecting five distinct types of such spaces (Fig. 4), the study engaged in systematic scenario development, designed to support an experiment using the Emotiv EPOC neuroheadset.

The study concentrated on five types of leftover spaces, each defined by distinctive landscape elements and design interventions. These types encompassed areas designated for planting, which included a variety of trees, shrubs, and grasses; spaces fitted with furniture; locations featuring water features, either dynamic or static; and sites illustrating diverse landscape styles, from orderly to irregular. These design interventions acted as benchmarks for evaluating the influence of different elements on the leftover spaces being studied.

Scenario development began with the sketching of Type 01: In-between Space, as illustrated by the authors (Fig. 5). The visual typology provided a foundational platform from which the scenarios were constructed. Each scenario was developed considering features closely related to design prototypes, encompassing landscape elements, styles, and strategies aimed at transforming typological spaces into potential areas of socio-environmental opportunity.

To ensure the reliability of the results, the study controlled for a series of variables, including neighborhood context, lighting conditions, proximity to the scene, participant height, spatial dimensions, materiality, and available facilities. Controlling these variables was essential to minimize outside factors that could affect the emotional data collected in different types of leftover spaces.

The experiment was conducted in a silent room, allowing for controlled EEG data capture via the Emotive EPOC neuroheadset. This device provided a map of channel locations designed to capture a

Fig. 3. The locations of the case studies in Tehran, Iran.

Table 3
Leftover spaces in Tehran, Iran: a selection of types.

Lots (Regular shape)	Lots (Irregular shape)	In-between space	Marginal space	Under bridge
				

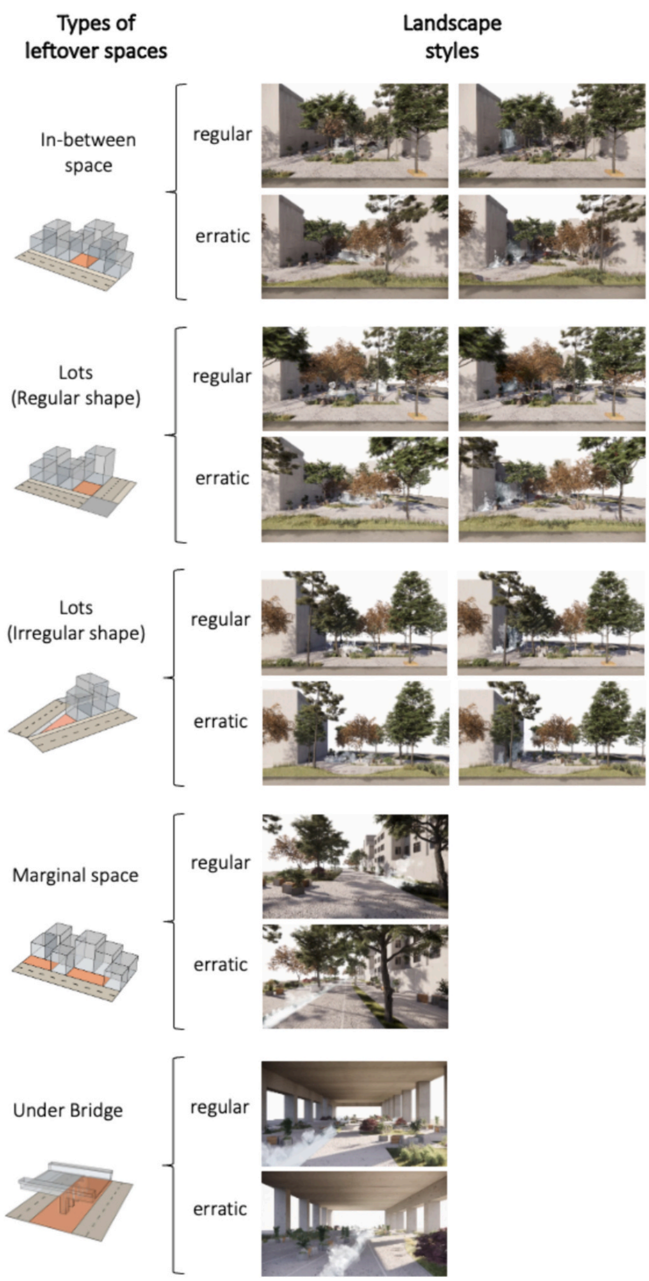

Fig. 4. Different types of leftover spaces and design sixteen scenes for testbeds.

spectrum of neural responses indicative of emotional states. To evaluate participants' individual emotional and psychological reactions, they were asked to complete the Stroop and Profile of Mood States (POMS) questionnaires both before and after recording their physiological responses. Alongside EEG data collection, participants were subjected to a survey before and after the experiment, using a comprehensive questionnaire to gain insights into their preferences and perceptions of the presented design scenarios.

The combination of EEG data and survey responses aimed to provide a holistic view of participant reactions to potential interventions in leftover spaces. Through this methodological framework, the study anticipated compiling a dataset capable of informing the role of design elements in altering the emotional landscape of urban environments, thereby contributing to the reclamation and revitalization of these often-overlooked areas.

3.4. Experiment with EMOTIVE

To measure emotional responses to landscape design, an experiment using the EMOTIVE tool was implemented. A diverse cohort of 33 participants, ranging in age from 31 to 70, was recruited for the study. These individuals were presented with sixteen distinct landscape design scenarios, and their emotional responses were recorded via EMOTIVE. Subsequent analysis of these responses was conducted using MATLAB software, enabling a rigorous assessment of the affective impact of each design.

3.5. Combination with questionnaires

After measuring the emotional responses using EMOTIVE, participants were invited to complete a questionnaire to gather additional insights into their demographic backgrounds and their personal preferences concerning landscape design. The questionnaire was developed based on previous studies and incorporated a Likert scale approach to quantify subjective preferences. The specific questions were asked to draw out preferences regarding design strategies and landscape elements.

3.6. Importance-Performance Analysis (IPA)

The study used Importance-Performance Analysis (IPA) to assess questionnaire results, focusing on the importance of different elements to participants and their satisfaction levels (Fig. 6). IPA is a method that allows the easy assessment of the discrepancies between the importance and performance of any service (Addas et al., 2021). IPA have been adapted across various fields such as tourism, healthcare, green space strategies, and education (Wong et al., 2011; Rey-Valette et al., 2017; Hua & Chen, 2019).

This study used the IPA to identify which design strategies and landscape elements were most important to residents and which strategies had the biggest impact on their emotional responses. For the assessment of the importance of POSs as perceived by participants, an improvement index for POSs was developed:

$$I_{pos} = \frac{IS_{pos} - PS_{pos}}{RI_{pos}} \quad (1)$$

$$RI_{pos} = \frac{IS_{pos} - IS_{pos_{-min}}}{IS_{pos_{-max}} - IS_{pos_{-min}}} \quad (2)$$

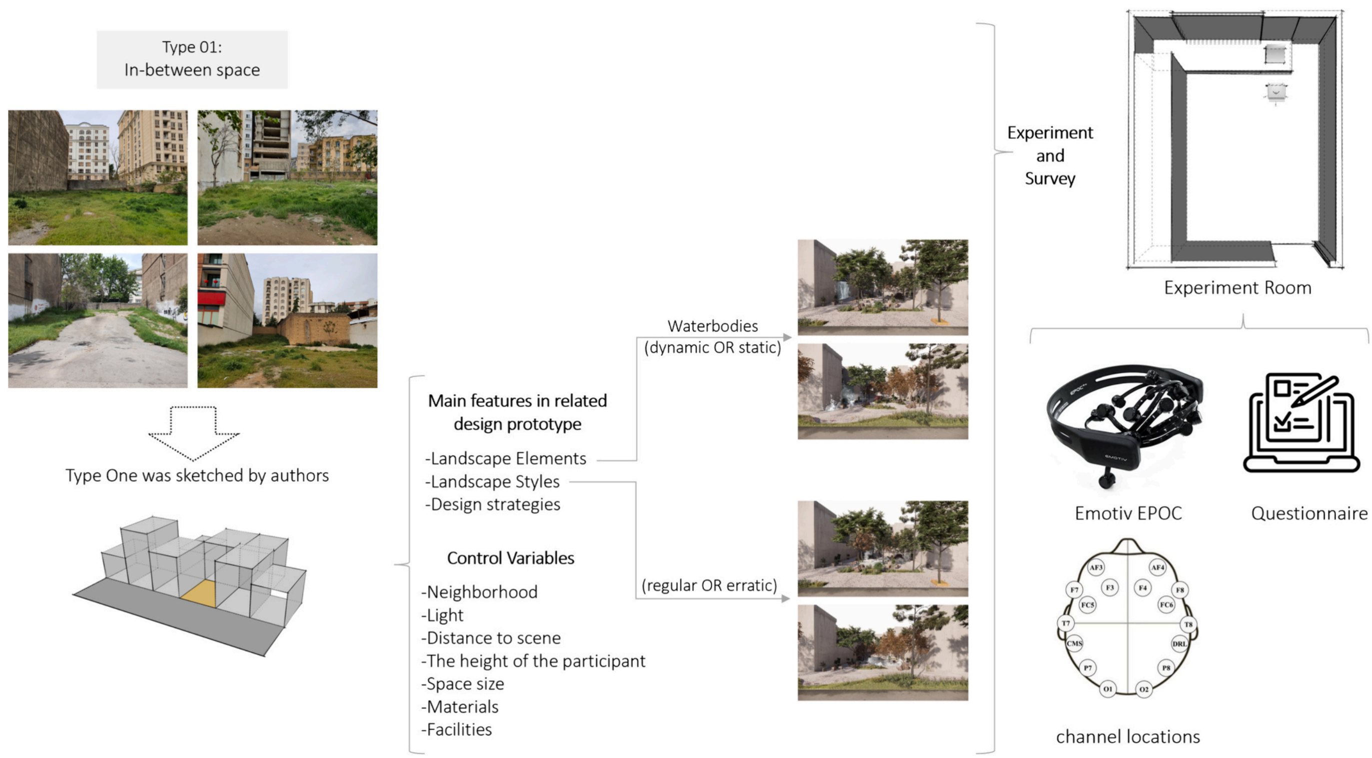

Fig. 5. Scenario development.

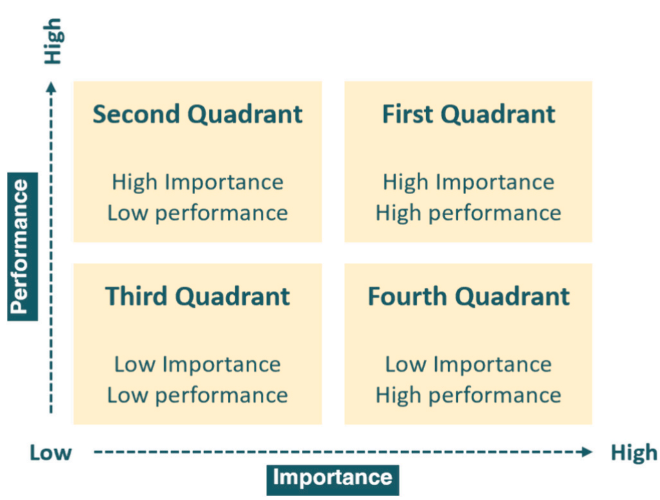

Fig. 6. The POS IPA grid (Martilla & James, 1977).

The IPA involved evaluating participant perceptions of 7 design Variables including 18 design strategies and 6 landscape Components including 19 Landscape Elements of small urban spaces using a five-point Likert scale for importance and a six-point Likert scale for performance, which included an 'Unable to Report' option. Importance was ranked using identifiers IA 1 to IA 5 (1 = Not at all important, 2 = Not very important, 3 = Somewhat important, 4 = Very important, 5 = Extremely important), and performance was ranked using PA 1 to PA 6 (1 = Not at all satisfied, 2 = Not very satisfied, 3 = Somewhat satisfied, 4 = Very satisfied, 5 = Extremely satisfied, UR = Unable to report).

3.7. Data description

This study involved 33 residents who volunteered in response to social media recruitment advertisments. However, data quality issues led to the exclusion of eight subjects, resulting in 25 valid participants (15 males and 18 females) with an average age of 22.84 (SD = 1.50) as shown in Table 4. They were informed about the study's criteria and precautions based on prior research (Jazi et al., 2017; Kim et al., 2019). These measures excluded individuals with cardiovascular or neurological conditions, risk of pregnancy, or a history of illegal drug use. Participants also had to refrain from caffeine, alcohol, and nicotine 24 h before testing. Those undergoing medical treatment, on their menstrual period, or with habitual alcohol use were not included. All participants possessed normal or corrected-to-normal vision (Elsadek et al., 2019).

4. Results and discussion

4.1. Results from the EMOTIV data

The Fig. 7 shows the changes and frequency levels for each of the six senses in the process of observing leftover spaces. The highest frequency levels are observed for the sense of Engagement. On the contrary, 'Ex' and 'Re', which we postulate to stand for 'Excitement' and 'Relaxation'

Table 4
The socio-demographic information of the participants.

Overall	
Age	
31–40	48.48 %
41–50	21.21 %
51–60	21.21 %
61–70	9.09 %
Gender	
Female	54.55 %
Male	45.45 %
Professional	
Yes	18.18 %
No	81.82 %

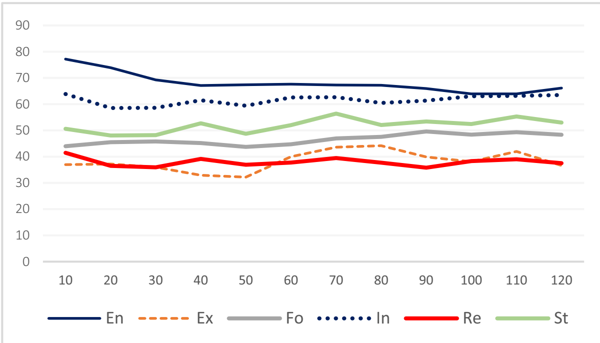

Fig. 7. Frequency levels for each of the six senses.

respectively, demonstrate the lowest frequencies, indicating these feelings are seldom aroused in such environments.

The consistently high frequency of Engagement across observations suggests that leftover spaces, often characterized by their unstructured and dynamic nature, have an inherent quality that engages individuals. This engagement could be attributed to the authenticity and rawness of these areas, which stand in contrast to the highly curated and controlled environments of planned urban spaces.

The infrequent stimulation of 'Excitement' and 'Relaxation' raises critical considerations for urbanism. It indicates a potential undervaluation in the design of leftover spaces regarding aspects that promote excitement and relaxation. Urban planners and designers might explore interventions to enrich these experiences, potentially transforming underutilized spaces into vibrant and restorative urban places.

The variability observed in the frequencies of 'Focus' and 'Interest' senses could be a focal point for future urban studies. These fluctuations may be influenced by multiple factors, such as the time of the day, the day of the week, the season, or specific events, which were not controlled for in this observational study.

The results underscore the complex sensory dynamics at play in leftover urban spaces and advocates for a more nuanced approach to their analysis and integration within the urban landscape. By understanding and harnessing the sensory impacts of leftover spaces, urban practitioners can create more inclusive and engaging urban environments.

The results of the Levene's test for assessing the equality of error variances in design option variables for emotions are shown. As observed, this test is significant for all options (sig < 0.05), and the error variance is the same among different options. As observed in Table 5, the effects of design options have become significant and have an impact on emotions.

The Fig. 8 separately shows the six senses examined in sixteen presented scenarios. This chart indicates that mental engagement is very high in the first scenario. The low interest in the second scenario may reflect a misalignment between the space's design and the users' expectations or needs. This could serve as a critical point for urban designers to reevaluate the elements that contribute to a space's appeal and the degree to which it encourages exploration and return visits.

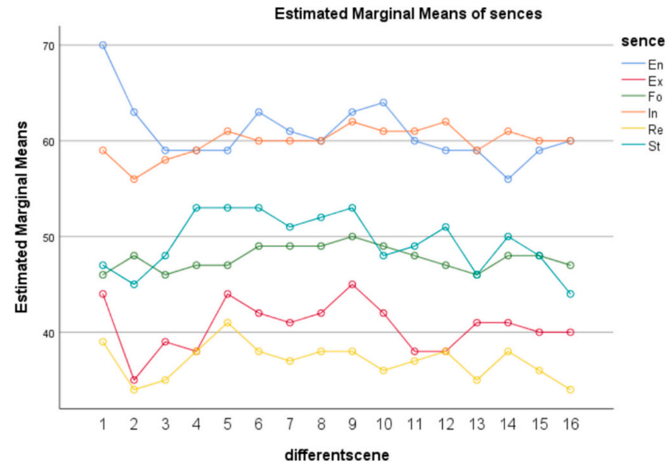

Fig. 8. The changes in the six senses in each of the samples.

Also, scenario number five has provided the most relaxation to individuals. The minimal relaxation experienced in scenarios two and sixteen could indicate a need for noise reduction, traffic calming, greening of spaces, or other stress-mitigating interventions.

The variability of sensory experiences across different urban scenarios underscores the importance of context-specific design and planning in urbanism. The data suggests that certain environmental cues and configurations can significantly influence mental engagement, interest, and relaxation.

Future research should aim to identify the specific elements within each scenario that contribute to the observed sensory responses. Qualitative methods such as interviews or focus groups could complement the quantitative data, offering deeper insights into personal and collective experiences of urban spaces.

Moreover, the Fig. 9 displays the changes and frequency levels for each of the six senses and for each shown option. The chart indicates significant changes in the samples designed related to marginal space.

The generally lower and stable frequencies of 'Relaxation' and 'Stress' indicate that marginal spaces may not inherently provide relaxation. This calls for deliberate design strategies to incorporate calming elements like water features or greenery for relaxation, and sensory stimuli such as textures and colors for stimulation. Also, the variable nature of 'Interest' highlights the challenge in sustaining interest in marginal spaces, which can be overcome by introducing varied and dynamic elements that evolve over time or provide seasonal interest. However, the stability of 'Focus' with occasional increases suggests that while marginal spaces may not consistently draw focused attention, certain interventions can create focal points that capture and retain the interest of the public.

4.2. Results from the importance-performance questionnaires

Using the importance-performance method, the importance, and the level of individuals' satisfaction with landscape elements in the respective spaces were calculated (Table 6). Then, the weight of each of

Table 5
Levene's test.

Tests of between-subjects effects						
Measure: senses						
Transformed variable: average						
Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Intercept	7,136,839.128	1	7,136,839.128	5899.042	0.000	0.971
senses	228,256.010	5	45,651.202	37.734	0.000	0.520
Error	210,510.455	174	1209.830			

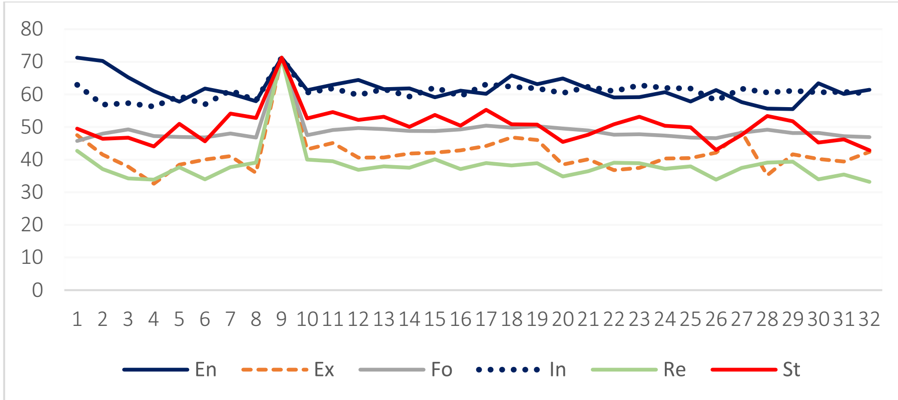

Fig. 9. Changes in frequencies in each of the samples.

Table 6
Entropy of importance-performance of landscape elements in the proposed scenarios.

Category	Elements	Code	Importance	Performance	Weight	Priority
Plants	Tree	E1	5	4.266	3.67	4
	Bush	E2	3.666	3.842	0.64	15
	Flower	E3	3.465	3.148	1.1	13
	Green cover	E4	3.744	3.815	0.27	18
Water feature	Static	E5	2.274	3.717	3.28	6
	Dynamic	E6	4.157	4.032	0.52	17
Topography	Flat, ladder	E7	2.983	3.701	2.14	8
	Gentle slope	E8	3.818	3.961	0.55	16
Landscape structure	Kiosk	E9	1.488	3.881	3.56	5
	Stall and pavilion	E10	1.536	4.412	4.42	2
	Cafe	E11	2.460	3.223	1.88	10
	Shade structure	E12	2.561	3.368	2.07	9
Paths & pavements	Fully paved	E13	3.293	3.493	0.66	14
	Partially paved	E14	3.001	3.390	1.17	12
	Gravel path	E15	2.940	2.907	0.1	19
Garden facilities	Stone	E16	2.499	3.732	3.08	7
	Lamp	E17	4.472	3.131	6	1
	Bench	E18	4.377	4.725	1.52	11
	Statue	E19	1.498	4.026	3.79	3

these elements, along with their priorities, was presented according to the formulas.

In the next step, the performance-importance analysis matrix is obtained. According to the participants, paths with softer materials and greater porosity such as gravel and flower planting are considered as less important factors. People have shown low satisfaction with these elements. These strategies will not pose a threat to the resilience of the spaces and will not be prioritized.

The element of lighting is the only one placed in the second zone that needs to be considered in the design. In the process of simplifying images and using fewer elements, this component was omitted in the initial examples. This element is of high importance and indicates the need for immediate corrective action in the intervention process.

As shown in Table 6, and Fig. 10, the structural elements were of little importance. They were not used in any of the initial examples and their near absence coincided with the participants' opinions. These elements can be eliminated as much as possible since they are not considered necessary by the participants. The tree element, green coverings, water dynamics, gentle slopes of paths, green spaces, and the presence of urban furniture such as benches were of the highest importance. These elements are in a relatively desirable condition and this status should be maintained.

The strategies that are in the first quadrant are those that users recognize as important and are satisfied with. This quadrant represents high performance and importance for dynamism, adaptability, diversity of native, near-native, and non-native plants from eight different species, the ability to walk and engage in social activities, accessibility for all users, and access to fresh air and light. The findings indicate that the indicators in this area are relatively satisfactory and should be maintained (Table 7, Fig. 11).

Diversity in shape, color, and size, cooling with shade, and ventilation, evaporation are in the "Possible overkill" quadrant (second quadrant). Although these strategies are of high importance, the findings indicate low satisfaction among participants. This quadrant shows that the strategies placed in this area need immediate corrective action and are a high priority for intervention.

The "Low priority" quadrant (third quadrant) includes strategies (mist and water features, connection at all scales, permeability, small environmental-related elements, functional redundancy, and minimal intervention) that people are less satisfied with and have low importance. These strategies are not threatening the resilience of spaces and do not need immediate correction (Table 7, Fig. 11).

Strategies in the "Possible overkill" quadrant (fourth quadrant) are as much as possible those that users are satisfied with; however, they do not consider these strategies essential. This quadrant indicates low importance and high performance and suggests the significance of these strategies. It is probably more beneficial to focus efforts and resources spent on these strategies in another part.

4.3. Results from the EEG data

This section presents a comprehensive analysis of the perceptual and neurophysiological responses to urban spaces, delves into the intertwined relationship between the subjective perceptions of urban spaces

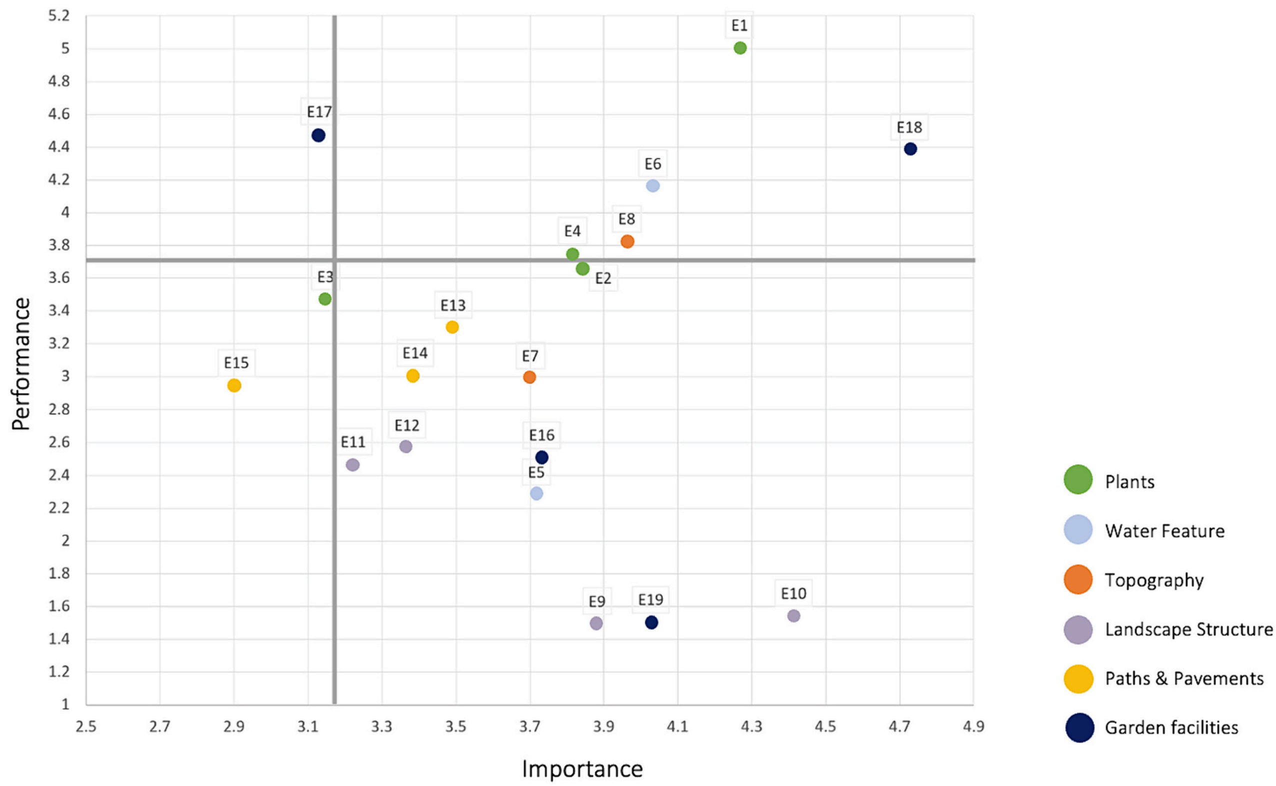

Fig. 10. Importance-performance matrix of landscape elements in the proposed scenarios.

Table 7
Entropy of importance-performance of design strategies.

Variables		Design strategies	Code	Importance	Performance	Weight	Priority
Flexibility		Dynamic landscape	S1	4.353	4.357	0.02	18
		Adaptability	S2	4.501	4.387	0.52	13
Diversity	Plants	Native, near-native, non-native	S3	4.746	4.455	9	10
		At list eight different species	S4	4.715	4.308	7	12
		Diverse shape, color, size	S5	4.641	4.189	5	14
	Water	Fond with water mist or fountain	S6	3.168	3.688	8	11
		Cooling based on shading	S7	4.549	3.884	2	17
		Ventilation, evaporation	S8	4.482	3.837	3	16
Activity		Walking	S9	4.915	4.690	1.1	11
		Social activity	S10	4.330	4.452	0.53	12
Connectivity		Connecting to all scale	S11	3.935	4.004	0.27	16
Accessibility		Openness	S12	3.374	3.985	2.06	6
		Physical accessibility to all users	S13	4.761	4.486	1.31	10
		Accessibility to natural light and fresh air	S14	4.962	4.889	0.36	14
Efficiency		Smaller elements	S15	3.301	4.048	2.47	4
Redundancy		Multiple components or pathways	S16	3.820	4.621	3.06	1
		Functional redundancy	S17	3.885	3.974268	0.35	15
		Minimal intervention	S18	3.896446	3.91472	0.07	17

and their objective neurophysiological impact. Through the lens of sophisticated analytical methods, this study dissects the classifications of spaces as ‘Leftover’ and ‘Designed’ (Fig. 12), alongside ‘Regular’ and ‘Erratic’ (Fig. 13), as perceived by study participants. This quantitative approach allowed for a detailed assessment of the model’s accuracy in reflecting human judgment on urban spatial aesthetics.

Complementing the perceptual data, the study analyzed neurophysiological signals captured through EEG, focusing on the frontal and temporal brain regions associated with cognitive function and emotional processing. The EEG data provided insights into the brain’s response to the visual and spatial characteristics of the urban designs, revealing patterns of brainwave activity that correlate with the perception of space. This analysis aims to understanding of how urban spaces are cognitively and emotionally processed by observers.

In the study of EEG data, a support vector machine (SVM) classifier was employed to distinguish between emotional responses to designed parks and residual spaces. Each participant’s data was divided into training and testing sets, with 80 % for training and 20 % for testing, ensuring an even distribution across classes. The classifier’s effectiveness is demonstrated by a robust accuracy of 92.8 %, as shown in the results of our confusion matrix.

4.3.1. Classification of urban spaces

The analysis began with the application of a confusion matrix to evaluate the efficacy of the classification model in distinguishing between ‘Leftover spaces’ and ‘Designed areas’ based on the perceptions of individuals. The model demonstrated a balanced classification with true positive rates of 46.5 % for Leftover spaces and 46.3 % for Designed

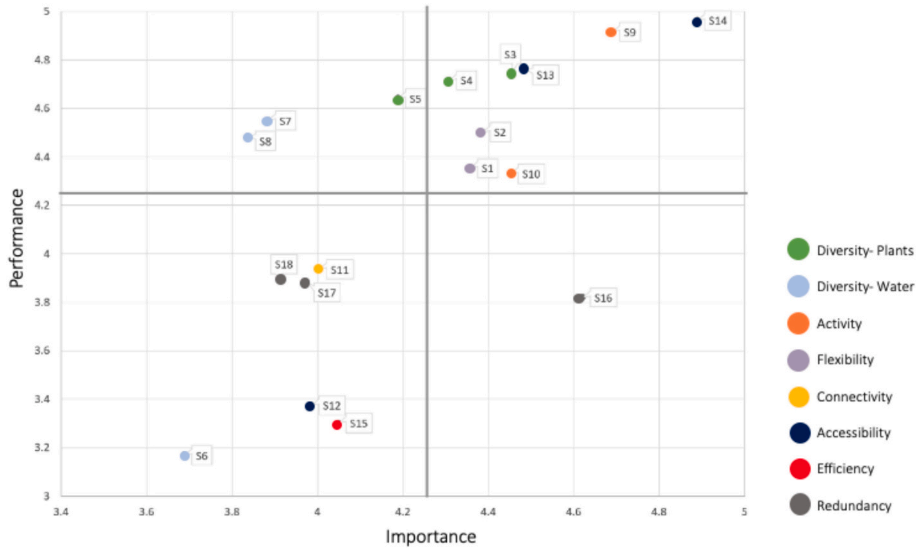

Fig. 11. Importance-performance analysis matrix of design strategies in the proposed scenarios.

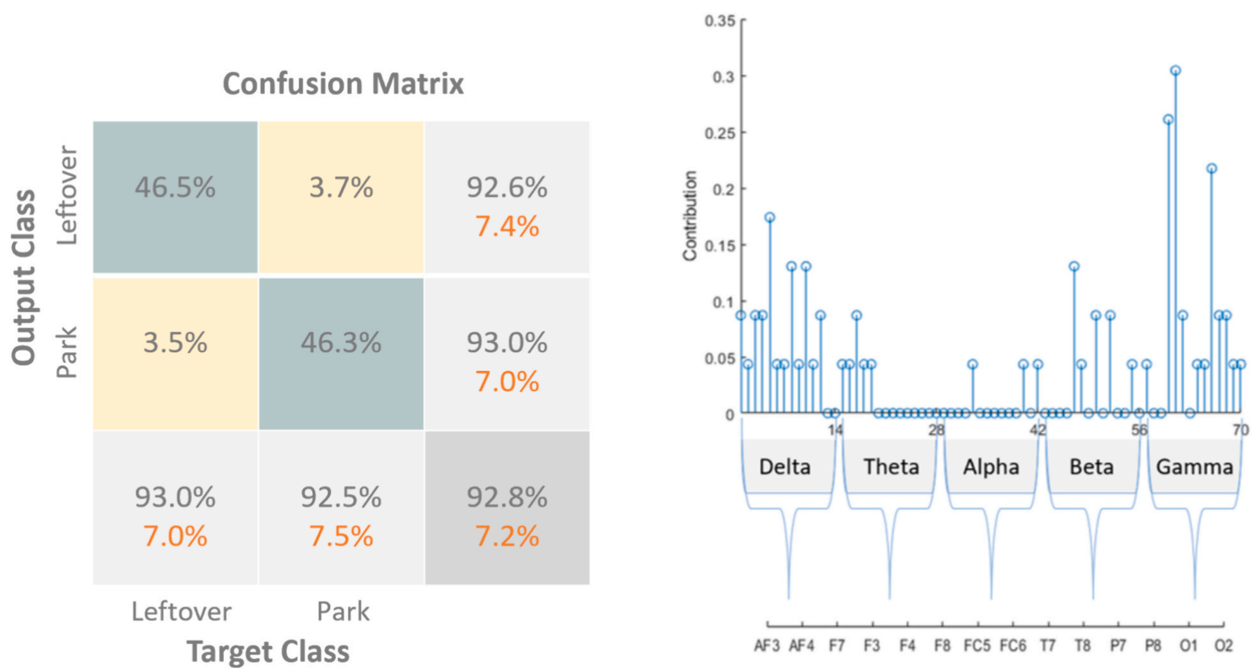

Fig. 12. (Right) Confusion matrix for leftover spaces vs. designed spaces classification, (Left) Neurophysiological response patterns.

spaces. Misclassification rates were low, with 3.5 % of Leftover spaces being classified as Park, and a 3.7 % error rate in the opposite direction. This indicates a satisfactory level of accuracy in the preliminary classification task, capturing a near-equal representation of both space types in terms of public perception (Fig. 12, Right).

4.3.2. Neurophysiological correlates

Further analysis was conducted using EEG data to understand the neurophysiological correlates of urban space perception. Brainwave patterns across Delta, Theta, Alpha, Beta, and Gamma frequencies were examined at multiple electrode sites. The data revealed distinctive patterns of brainwave activity associated with the perception of urban spaces. Notably, the frontal electrode sites F3 and F4 showed pronounced activity, suggesting these regions may be pivotal in processing the visual and spatial aspects of urban spaces (Fig. 12, Left).

4.3.3. Brainwave contributions to perception

Delta and Theta waves, typically associated with sleep states, showed minimal variance, implying a state of wakeful engagement during the observation of urban scenes. Alpha waves, indicative of relaxed alertness, did not show significant variations, suggesting a consistent level of relaxation across observations of both Leftover spaces and Designed spaces. The Beta and Gamma frequencies, associated with active cognitive engagement and processing, displayed more variability across the electrode sites. This variability could reflect the cognitive effort participants employed to interpret the scenes, potentially correlating with the complexity or appeal of the urban space design.

4.3.4. Correlation between brain activity and space classification

The highlighted activity in the F3 and F4 sites aligns with the prefrontal cortex, which is involved in planning complex cognitive behavior and decision-making processes. The prominence of activity in these

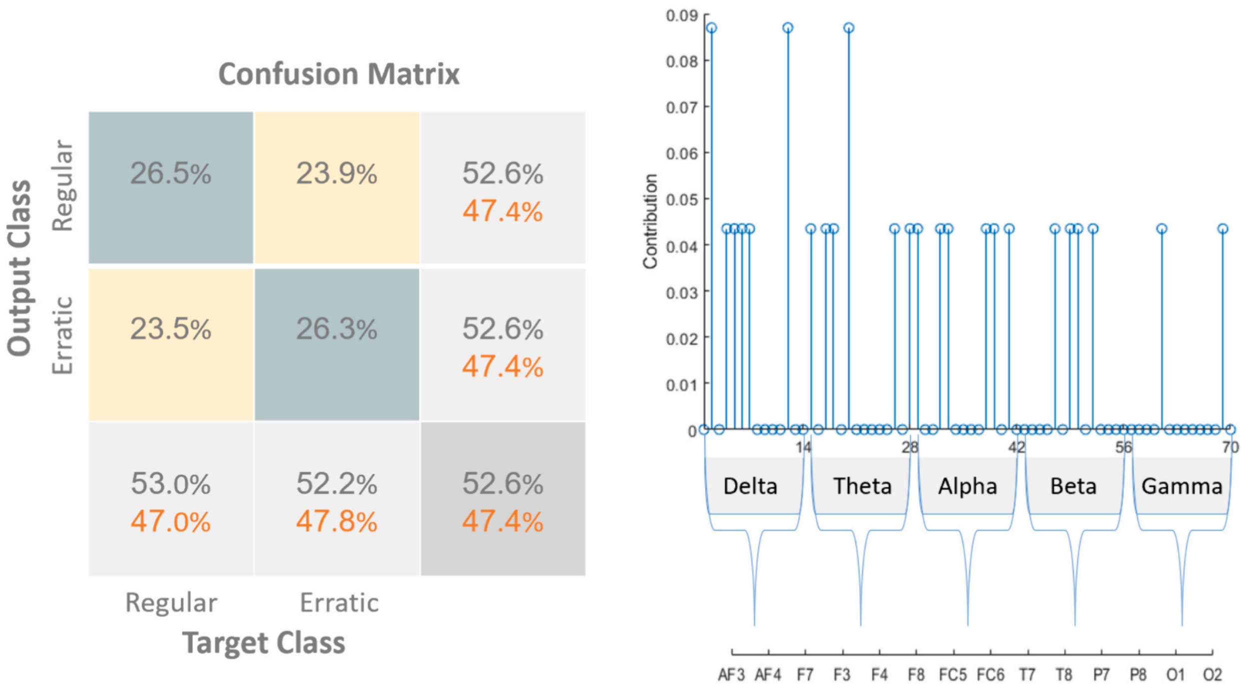

Fig. 13. (Right) Confusion matrix for regular vs. erratic urban design classification, (Left) Neurophysiological response patterns.

areas may suggest that participants' perception of the 'Park' versus Leftover spaces involved higher-order cognitive processing. This finding aligns with the notion that well-designed urban spaces may engage more complex cognitive functions, reflecting the participants' conscious and unconscious responses to their surroundings.

The results of the EEG analysis, in conjunction with the classification accuracy of this model, underscore the potential of neurophysiological measures in urban studies. The brainwave patterns provide a window into the cognitive and emotional responses elicited by different types of urban spaces. The current findings suggest that the design of leftover spaces or even redesign of urban spaces has discernible impacts on cognitive engagement, as evidenced by the brain activity of participants. This has profound implications for urban design, emphasizing the need for an empirical, human-centered approach in the creation and refurbishment of urban spaces to foster favorable cognitive and emotional responses among urban dwellers.

4.3.5. Classification of urban design perceptions

The investigation into the classification of urban spaces as perceived by individuals utilized a confusion matrix to evaluate the capability of the model in differentiating between 'Regular' and 'Erratic' designs. The results revealed a moderate level of classification accuracy, with true positive rates of 26.5 % for 'Regular' and 26.3 % for 'Erratic' designs. The rates of misclassification were comparable, with 'Regular' designs being mistaken as 'Erratic' in 23.9 % of cases, and 'Erratic' designs being misclassified as 'Regular' in 23.5 % of instances. This equates to a recall of approximately 52.6 % for 'Regular' and 52.8 % for 'Erratic' designs, and a precision of 53.0 % for 'Regular' and 52.2 % for 'Erratic' predictions. These figures highlight the challenges in achieving a high degree of distinction in public perception between the two design types using the current model (Fig. 13, Right).

4.3.6. Neurophysiological responses to urban designs

The EEG data captured during the perception of the urban spaces were analyzed for brainwave patterns across the Delta, Theta, Alpha, Beta, and Gamma frequencies. The contribution of these brainwave bands was consistent across all frequencies, suggesting no significant dominance of any particular state of consciousness during the observation of both 'Regular' and 'Erratic' designs. The most notable observations were made at the frontal electrode sites (AF3, AF4, F3, F4), and the temporal site (T8), which showed a more pronounced contribution, albeit still within low amplitude ranges (Fig. 13, Left).

4.3.7. Integration of perceptual and neurophysiological data

The integration of the classification performance with the EEG data suggests a nuanced interplay between the perception of urban space design and neurophysiological response. The frontal brain regions, involved in complex cognitive processes such as decision-making and emotional processing, were highlighted, yet the low amplitude of brainwave contributions indicates a subtle engagement with the urban spaces regardless of the design type. This could imply that the perceptual differences between 'Regular' and 'Erratic' urban designs are not as pronounced as expected or that the current methods of measurement require refinement to capture the subtleties of human perception in urban settings.

These findings point to a potential alignment between the cognitive processing of urban space design and the subtle neurophysiological responses as captured by EEG. The modest distinction in perception between 'Regular' and 'Erratic' designs, as suggested by the balanced classification accuracy, presents an opportunity for further research. Future studies may benefit from an exploration into more sensitive neurophysiological markers or a refined approach to classification that can more distinctly capture the essence of urban design as perceived by the public. The insights gained from this study lay the groundwork for advancing our understanding of the cognitive and emotional impacts of urban design and highlight the importance of an empirical approach in urbanism that is attuned to the human experience.

The observed patterns in frontal EEG asymmetry in this study may elucidate significant variations in the emotional regulation of individuals as they interact with urban spaces. Consistent with Goodman et al. (2013), our analysis indicates that increased activity in frontal brain regions could be linked to heightened sensitivity to the emotional valence of urban designs. Individuals exhibiting greater activity in the left frontal regions, as opposed to the right, appeared to exhibit greater impulse control and, consequently, more effective emotional regulation (Zhang et al., 2020).

This asymmetry, reflected in the current data, suggests that participants with a dominant left-frontal activity might adopt a more passive perspective when engaging with urban spaces. This finding aligns with the “Differences in Frontal EEG Asymmetry during Emotion Regulation between High and Low Mindfulness Adolescents” (2021), further substantiating the premise that the perception of spatial aesthetics can activate visuospatial processing areas within the fronto-parietal network. Bower et al. (2019) have similarly highlighted the role of these regions in the cognitive and motor processes involved in the spatial evaluation.

Moreover, the design configuration and landscape composition are pivotal in shaping visitors’ emotional responses, as evidenced by our EEG data and supported by Kong et al. (2022). The finding suggest that urban design exerts a substantial influence on the emotional and cognitive processing of individuals, highlighting the impact of design elements on the well-being and psychological state of urban inhabitants. The EEG data, particularly the frontal asymmetry, could be indicative of a biologically embedded response to the aesthetic and functional aspects of urban design, offering a unique perspective on the intersection of urbanism and neurophysiology.

4.4. Conclusion

This study represents an endeavor in the integration of neurophysiological data, specifically EEG, with traditional urban planning research methods to understand the cognitive and emotional responses to urban spaces. Through a deep analysis encompassing Importance-Performance questionnaires, EMOTIV data, and EEG readings, the current study investigated the potential value of redesigning small vacant lands based on how individuals perceive resilience strategies, and Landscape Elements, as well as interaction with various urban environments.

The innovative significance of this study lies in its integration of traditional methods with EEG data on a small scale within landscape contexts, providing a quantifiable measure of engagement with open spaces. This cross-disciplinary approach not only pioneers new methodological practices but also enriches our understanding of how minor modifications in urban landscapes can influence human behavior and well-being, particularly when resources are limited.

The findings reveal that sensory experiences in urban spaces, particularly in leftover and marginal areas, are complex and multifaceted. High levels of engagement in these spaces suggest that their unstructured and dynamic nature has a unique appeal, contrasting starkly with more planned and controlled urban environments. However, the relatively lower levels of excitement and relaxation observed indicate a potential area for improvement in urban design. These insights can guide urban planners and landscape architects in transforming vacant lands into vibrant, inclusive, and restorative parts of the urban fabric.

The Importance-Performance analysis further illuminated the public’s perception of various landscape elements and design strategies. This approach highlighted the elements that are both important to users and performing well, such as dynamic landscapes and diverse plant species, alongside those that require immediate attention or are deemed overkill in the current urban design context.

From a neurophysiological standpoint, the EEG data offered a perspective on how urban spaces impact cognitive and emotional processing. The frontal and temporal brain regions, known for their roles in cognitive function and emotional processing, displayed distinct patterns of activity in response to different urban designs. This not only validates the subjective perceptions captured through surveys but also opens a new frontier in understanding the urban experience through a neuroscientific lens.

To transform leftover sites into vibrant and effective small green spaces, resilience design strategies informed by user feedback and performance data can be implemented. These strategies can enhance satisfaction and engagement. Spaces that align with user expectations tend to resonate well, as indicated by high mental engagement in certain scenarios. Incorporating features such as dynamic water elements, diverse plant species, and interactive installations can significantly enhance sensory engagement.

To address areas of minimal relaxation, integrating elements like noise-reducing vegetation, traffic calming designs, and shaded seating areas can create a more clam and inviting environment. Regular maintenance and periodic updates are crucial to keeping the environment fresh and engaging, which is essential for encouraging repeat visits.

Adaptive and dynamic designs that change seasonally or offer varying experiences can sustain long-term interest. Introducing varied textures, colors, and scents through landscaping can create focal points that capture and retain public interest, encouraging exploration and repeat visits. Furthermore, each site should be designed with its unique characteristics in mind, considering its natural topography and existing features to foster a sense of place and community connection.

In conclusion, this study underscores the importance of a multidisciplinary approach in urban planning and design, where traditional methods are enriched with neurophysiological insights. The findings advocate for a more human-centered approach in urbanism, emphasizing the need to consider both the physical and psychological well-being of residents in the design process.

4.5. Limitations

This research offers valuable insights into how small green spaces enhance psychological well-being, yet it recognizes several limitations that highlight areas for future inquiry. Initially, it examines only the immediate neural and psychological impacts, overlooking the potential long-term effects on well-being. Additionally, the specific use of EEG and EMOTIV technologies may not capture the full spectrum of human emotional and cognitive responses due to their inherent focus on particular brain regions and activities. Moreover, the generalizability of these findings may be limited by the socio-cultural and geographical context.

It is important to note that this study was conducted during the COVID-19 pandemic, which may have influenced the results in several ways. Firstly, participants were less willing to wear headsets, which restricted our ability to collect data from a broader target group. Additionally, the integration of an eye tracker device with the EEG setup was not feasible, limiting the depth of data regarding visual attention and spatial engagement. Moreover, the pandemic may have influenced participants’ preferences and emotional responses, as well as the EEG data, due to the unique social and psychological impacts of the COVID-19 period. These factors should be considered when interpreting the study’s findings and planning future research.

4.6. Future directions

Future research should continue to explore this intersection, further refining our understanding of the complex relationship between urban spaces and human responses, This exploration should focus on both psychological (e.g., reduction in stress, improvement in mood disorders) and physical (e.g., improved air quality, physical fitness).

Additionally, examining the long-term impacts of these redesigned spaces on urban resilience and climate adaptation is crucial. Such research should assess how these spaces contribute to urban sustainability over time, influencing community dynamics, biodiversity, and ecological balance. Comparing the effectiveness of SVL transformations across different cities or countries with varying climates and cultural contexts could also provide a broader understanding of how cultural and environmental factors influence the success of urban green spaces.

Furthermore, developing frameworks that enable efficient collaboration between government, local communities, and private stakeholders is essential. Examining the role of policy and governance in facilitating the transformation of SVLs into green spaces will be pivotal in creating effective collaborative frameworks. In this regard, Involvement of the community through workshops can be pivotal. These sessions should aim to integrate public preference with scientific insights, ensuring that the green spaces meet the users' needs both at a functional and a psychological level. Such collaborative efforts can also foster a greater sense of community ownership and stewardship over these spaces. Lastly, studying the integration of art and cultural elements into SVLs, such as through community art projects, performances, and cultural gatherings, can significantly enrich the community's cultural fabric. This dual focus on both the social and functional aspects of SVLs will not only enhance the aesthetic and emotional appeal of urban areas but also contribute to a more comprehensive approach to urban planning and development.

CRediT authorship contribution statement

Maryam Naghibi: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used CHATGPT to check for typos and grammar errors. After using this tool/service, the author(s) reviewed and edited the content as necessary and take(s) full responsibility for the contents of the publication.

Declaration of competing interest

The author declare that they have no conflict of interest, financial or otherwise.

Data availability

Data will be made available on request.

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