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Brainwave Dynamics: Neurophysiological Responses to Enclosed Courtyards for Mental Wellbeing in Educational Contexts

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Abstract

University students are subject to various demands in their role as academics. Such pressures tend to amplify emotional distress, making them more susceptible to mental health hazards. This study investigates the influence of enclosed courtyards on students' mental health within educational facilities, focusing on their distinct spatial configurations, such as semi-open layouts and vegetation cover, as well as their effects on intellectual functioning and well-being. The research used electroencephalography (EEG) to examine brainwave activity and quantify the influence of the spatial design of enclosed courtyards on the mental and emotional well-being of students. An experiment with 16 students and EEG measurements was conducted in the Faculty of Engineering courtyard at Egypt's Ain Shams University in Cairo, providing 60–70% statistical power to detect medium effect sizes (Cohen's d = 0.5, α = 0.05), which is sufficient for exploratory research. The study explores the psychophysiological implications of the brain's electrical signals as neurological measurements, such as alpha and theta brainwaves, in order to assess individuals' relaxation, restoration, and attention levels. The findings show that natural characteristics of the courtyard, expansive space, and visual stimuli have a significant effect on restoration and attention. While the sample size is limited and the design is context-specific, the results provide preliminary evidence that meticulously designed enclosed courtyards can improve students' mental well-being. These findings invite further multi-site validation to assess generalizability. This study contributes to the expanding domain of neurolandscape" by demonstrating the interplay between built environments and mental health in educational contexts.

Keywords: neurolandscape; courtyards; educational campuses; mental well-being; neurophysiological approach; psychophysiological approach; EEG; neural activity

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1. Introduction

College students have several pressures, including role transitions, academic responsibilities, interpersonal interactions, and employment obligations [1]. These pressures frequently exacerbate emotional suffering, heightening susceptibility to mental health issues. Thus, this could impact students' physical and mental health, as well as their

academic performance, potentially leading to social isolation and negative behaviors [2]. In psychology, anxiety is defined as intrusive and distressing emotions concerning perceived threats, manifesting as excessive worry [3]. Noticeably, a considerable proportion of students worldwide experience anxiety-related challenges [4–6]. This underscores the critical role of learning environments in shaping not only academic experiences but also intellectual development and emotional well-being. Substantial evidence from environmental psychology further affirms that physical settings exert a profound influence on educational outcomes, including attention, motivation, and mental health [7,8].

Within this framework, learning environments present a paradox—while they have the potential to foster positive psychological states, they can also exacerbate mental health difficulties and hinder academic performance. Empirical studies indicate that poorly designed educational spaces contribute to heightened stress, increased anxiety, and diminished academic achievement [9,10]. In contrast, well-structured environments can promote relaxation (as defined in Stress Recovery Theory—SRT), enhance cognitive performance (as supported by Attention Restoration Theory—ART), and act as a restorative sanctuary, i.e., a space that supports psychological recovery and attention renewal [2]. These theories—SRT and ART—provide a theoretical foundation to explain how certain spatial and environmental features can positively influence mental states [11]. Additionally, prior research has demonstrated that exposure to natural elements, such as open spaces, greenery, and enough sunlight, has been scientifically linked to enhanced cognitive function and decreased stress levels, thereby fostering an environment that is conducive to successful learning [12]. This ambivalent outcome highlights the need for specific interventions designed to enhance these environments to successfully promote student mental health and academic achievement.

In terms of spatial configuration, courtyards—enclosed or semi-enclosed outdoor spaces within institutional settings—stand out as significant architectural features. Historically, courtyards have served as communal centers in educational institutions, promoting social interaction [13]. Despite their acknowledged importance, the psychophysiological impacts of courtyards with varying spatial configurations on students remain insufficiently explored, particularly through objective, real-time measures such as brainwave analysis. Furthermore, specific spatial design features that influence mental well-being may be adaptable, allowing their effectiveness to be optimized within courtyard settings. Courtyard environments encompass a variety of spatial and visual attributes that are likely to influence the neurophysiological responses related to attention and emotional well-being. Elements such as vegetation, natural light, and surface finishes constitute the visual stimuli that shape users' sensory experiences within space [14]. Simultaneously, features like layout shape, spatial proportion, degrees of enclosure, and the connectivity between different zones reflect the spatial configuration that defines the courtyard's structural logic [14,15]. These environmental qualities are not merely esthetic or functional, they are theorized to engage with cognitive and emotional processes, potentially triggering measurable changes in brain activity [16,17]. As such, understanding how these attributes interact with users on a neurological level is essential for developing courtyard designs that actively support mental restoration and cognitive performance.

Therefore, this study intends to shed some light on two main issues through answering the following questions:

1. How do the spatial configurations of enclosed courtyards in educational settings influence students' neurophysiological responses, as measured by brainwave activity (e.g., alpha and theta waves)?

2. What is the relationship between the visual stimuli of enclosed courtyards (e.g., existing natural elements) and psychophysiological outcomes like relaxation or reduced anxiety in students?

In an enclosed courtyard in the Faculty of Engineering at Ain Shams University, the authors utilized EEG as a non-invasive technology to record the electrical activity of the brain. Although subjective methods such as surveys and interviews have traditionally been used in post-occupancy evaluations, EEG (electroencephalography) presents a more direct, real-time, and non-invasive method to assess the cognitive and emotional effects of designed spaces. Previous environmental and architectural studies have successfully employed EEG to examine how physical settings influence brain activity, including attentional states, stress recovery, and emotional arousal [18–23]. These studies validate EEG's capacity to detect physiological indicators by translating them into psychological states.

Following this approach, this article presents evidence-based insights on designing courtyards that enhance students' mental well-being. This research not only presents immediate findings but also advances the emerging field of the "neurolandscape", which combines open space design principles with neuroscience in order to develop human-centered environments, thereby influencing educational design practices more broadly.

2. Shaping Minds: Educational Spaces and Students' Mental Health

University campuses serve as more than venues for formal instruction; they are dynamic ecosystems where students engage extensively in activities that demand sustained concentration and cognitive effort [11,24]. Both indoor and outdoor settings within these campuses play a pivotal role in shaping a holistic learning experience that extends beyond conventional academic boundaries [25]. This interplay between people and their environment is best understood through two foundational theories—Attention Restoration Theory (ART) and Stress Recovery Theory (SRT).

Attention Restoration Theory (ART) offers a framework for comprehending the mechanisms by which natural environments restore cognitive resources [8]. It differentiates between directed voluntary attention and spontaneous involuntary attention. Directed voluntary attention is employed in challenging tasks such as studying; it depletes rapidly and results in mental fatigue. This type of attention requires active, conscious effort to focus while suppressing distractions. On the other hand, spontaneous involuntary attention, or fascination, is effortless and elicited by natural environments [26]. ART also delineates four facets—being away, extent, fascination, and compatibility—that facilitate the restoration of directed attention in environments [8]. SRT states that looking at scenery containing natural elements like greenery or water creates positive emotions and feelings like interest, pleasure, and calm, as well as having a restorative effect [18].

This connection between the environment and mental health is particularly relevant given the escalating mental health concerns among university students, with 86% reporting elevated stress, 62% experiencing anxiety, and 14% suffering from severe depression [27–29]. As highlighted by The Ottawa Charter, health is cultivated in everyday settings where individuals participate in studying, working, playing, and loving [30]. Hence, universities have a considerable capacity to improve mental well-being by creating environments that balance cognitive demands with opportunities for rest and recuperation [30]. Mental well-being is a state of emotional, psychological, and social health that helps people deal with life's obstacles, maintain their equilibrium, and find fulfillment [31]. Additionally, several interrelated processes support mental health; among these, relaxation and restoration are crucial elements that support psychological resilience and recovery. Despite their close relationship, the two processes have different purposes. After stress or mental exhaustion, restoration is the process by which diminished cognitive, intellectual, and

emotional resources are recovered. Rebuilding internal capacities and disengaging from stressors are usually linked to this. There are two primary categories of restoration—cognitive restoration, which involves regaining mental focus and attentional control, and emotional restoration, which is defined by minimizing negative effects and promoting positive mood [32,33].

Relaxation, on the other hand, is a more immediate, subjective state characterized by calmness and decreased arousal. Relaxation promotes a brief suspension of stress or alertness rather than the rebuilding of depleted resources, in contrast to restoration, which is goal-directed and frequently necessitates a certain amount of time or environmental quality to achieve recovery [34]. Through careful case studies, these psychological effects have been examined in relation to outdoor space design. The following (Table 1) illustrates the various ways that educational outdoor spaces can impact students' mental health through a range of psychological effects [34–36].

Table 1. Different forms of educational outdoor spaces and mental well-being.

Spatial Form	Description	Psychological Effect
Plaza	Central plaza for gatherings and events	Fosters social interaction and reduces stress
Courtyards	Spaces surrounded by buildings that could include greenery and seating	Encourages relaxation and restoration; enhances collaboration
Pedestrian promenades	Pathways connecting campus areas	Promotes mental relaxation and focus
Main building quadrangle	Square spaces surrounded by academic buildings	Enhances community; fosters informal learning
Amphitheatre	Venue for cultural events	Boosts creativity and mental rejuvenation
Lawns and gardens	Green spaces	Provides mental relaxation; enhances creativity
Tree-lined pathways	Shaded paths for leisure	Encourages peaceful reflection

Source: [34–36].

Finally, mental well-being is underscored by the dynamic interaction between people and their settings, suggesting that well-designed places might serve as health resources [6,37]. In this article, the authors will focus on courtyards as spaces for restoration. The article will tackle courtyards not as a generic form but while reflecting on their spatial configuration and the encompassed visual stimuli presented in the landscape design of the courtyard.

3. The Courtyard Concept: Spatial Configuration and Visual Stimuli

Courtyards are architectural features that have a significant historical and contemporary role in educational settings [38,39]. Courtyards, as the article's focus, serve as vital spaces that enhance students' mental well-being and learning experiences. These environments provide visual and sensory stimuli that alleviate mental fatigue and promote a sense of community, meeting students' needs for reflection and social interaction [40]. Defined as enclosed or partially enclosed areas surrounded by walls or buildings, courtyards have been an inherent element of building design for centuries, with their beginnings being traced back to their inception in Sumer and Pharaonic Egypt [17]. Originally intended for protection, they have now turned out to be the central points of dwelling, occupation, and interaction, driven by social and cultural forces [41]. In educational contexts, court-

yards provide relief from the mental pressures of academic life, facilitating relaxation and socialization [13].

Previous research has investigated the influence of courtyard designs as outdoor spaces on human well-being, particularly through the analysis of spatial configurations and visual stimuli generated by landscape features. In terms of visual stimuli, courtyards characterized by greenery and natural lighting provide environments that foster relaxation, social interaction, and informal learning [10,40,42,43]. Elements such as comfortable seating, shade, and vegetation further promote mental restoration and strengthen students' sense of belonging [16,17,44]. Incorporating water features, such as fountains, has been shown to enhance happiness, create a sense of openness, and significantly reduce anxiety levels ($p < 0.01$, OR = 0.504) [13]. Collectively, these design components cultivate tranquil settings that alleviate stress and support mental well-being [10,24].

The spatial configuration of courtyards is essential to determining how they affect students' mental and physical health [45]. For instance, the use of diverse shapes in courtyards (e.g., rectangular, square, U-shaped, or curvilinear) could aid in taking optimum advantage of natural light and ventilation for ultimate comfort [45]. U-shaped courtyards, for example, are commonly east–west-oriented with a southern opening, improving ventilation and shading, making learning areas more comfortable for students [40].

Crucial design factors such as courtyard dimensions, degree of enclosure, and shape significantly influence psychological implications. Expansive, open layouts provide increased natural illumination, enhancing visual attractiveness, whereas square courtyards with elevated walls provide superior shade, resulting in more comfortable and cooler environments [10,38]. In high-density campuses, small courtyards situated near study areas are particularly beneficial as they offer immediate access to tranquil spaces that promote concentration and relaxation [24,46].

Ultimately, courtyards in educational environments serve as effective instruments for enhancing mental health and improving learning outcomes by integrating historical significance with modern design principles. Exquisitely structured courtyards, distinguished by deliberate shapes, orientations, and natural elements, are vital components of campus settings that affect academic achievement and psychological well-being, as colleges aim to address students' mental health challenges.

The following tables (Tables 2 and 3) show how the landscape elements that represent the visual stimuli and spatial configurations of courtyards would create specific psychological effects, according to previous studies.

Table 2. Spatial configurations of courtyards and their psychological effects.

Aspect of Configuration	Description	Psychological Effect	Brainwave Band Associated
Degree of enclosure	High enclosure (elevated walls) provides shade and cooler environments.	Mental restoration and relaxation	Alpha and Theta
	Open layouts increase natural illumination.	Improved visual attractiveness; reduced stress	Alpha, Beta, and Gamma
Shape	Rectangular/square courtyards optimize shade and comfort.	Mental restoration; reduced anxiety	Theta and Beta
	U-shaped courtyards (east–west orientation) improve ventilation.	Enhanced comfort and relaxation	Alpha
	Curvilinear shapes promote natural movement and openness.	Increased happiness; reduced tension	Gamma, Beta, and Alpha

Table 2. *Cont.*

Aspect of Configuration	Description	Psychological Effect	Brainwave Band Associated
Dimensions	Expansive courtyards enhance natural light.	Improved mood; reduced fatigue	Alpha, Beta, and Theta
	Small courtyards near study areas offer quick access to tranquility.	Better concentration and relaxation	Alpha

Source: [10,24,38,46].

Table 3. Visual stimuli of courtyards and their psychological effects.

Visual Stimuli	Description	Psychological Effect	Band Associated
Greenery (vegetation, trees, and shrubs)	High green coverage (GVI 30–90%)	Pleasure; relaxation; stress reduction	Alpha, Beta, and Theta
Water elements (fountains and ponds)	Presence of blue spaces (BSs)	Happiness; openness; reduced anxiety	Gamma and Beta
Comfortable seating and shade	Encourages social interaction and rest	Sense of belonging; mental restoration	Alpha Theta
Natural lighting	Optimized through courtyard shape and orientation	Reduced mental fatigue; improved focus	Alpha and Beta
Color variation and naturalness	Brightness, rhythm, and order in landscape design	Relaxation	Alpha
Landscape diversity (lawn, forest, and horticulture)	Mixed natural elements	Alleviation of anxiety and depression	Alpha and Beta
Landmark features	Visual cues providing feelings of safety	Cognitive wayfinding and navigation	Theta

Source: [10,13,40,42].

4. Materials and Methods

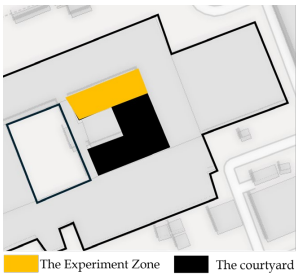
4.1. Study Area

The courtyard is an enclosed outdoor space located within the Faculty of Engineering at Ain Shams University, Cairo, Egypt, positioned centrally within the faculty's building complex; it is surrounded by academic structures. The following table (Table 4) depicts a full description of the courtyard.

Participants were seated on the most enclosed side of the U-shaped courtyard to test the enclosure's impact on relaxation, enabling visibility and a sense of the entire space while shielding them from noise disruptions from other students and passersby. This location, identified as the calmest area, was also the most unfamiliar to participants, chosen to assess initial reactions by reducing the influence of habituation or personal associations. While other orientations were considered, this specific site was prioritized for its controlled conditions and enclosure benefits.

The experiment was conducted from November to January, on clear days in the winter season. It took place between 1:30 p.m. and 4.30 p.m. This time slot was chosen to occur after the break period in order to minimize external noise, as fewer students were present in the courtyard during these hours, as well as to ensure consistent environmental conditions and natural lighting while no artificial lighting was used. Throughout the experiment, the temperature fluctuated between 22 °C and 26 °C. This indicates that the weather was stable and temperate.

Table 4. Courtyard description.

Parameter		Description		
Spatial Configuration	Shape and Dimensions	Rectangular courtyard with a narrow, elongated layout. Yellow-marked area in schematic plan indicates the experiment zone where students were seated, as seen in Figure 1.	Approx. 9 m × 17 m (153 m^2)	
	Enclosure	Surrounded on four sides by multi-story buildings (3–4 stories), creating an enclosed confined space.	Building height: ~12–15 m; height-to-width ratio ≈ 0.8–1.0	
Visual Stimuli as seen in	Vegetation Coverage	Dense greenery with large canopy trees, shrubs along building edges, and low vegetation near seating.	~35% of courtyard area	
	Hardscape Coverage	Brick paving for central walkway.	~65% of courtyard area	
	Vegetation-to-Hardscape Ratio	Ratio reflecting greenery versus paved/constructed surfaces.	2:3 (35% vegetation: 65% hardscape)	
	Furniture and Shading Structures	1. Shade provided naturally by tree canopies;. 2. Wooden-slat benches. 3. Concrete bollards.	1. No artifital shading. 2. Four 3. Three	

Source: Authors.

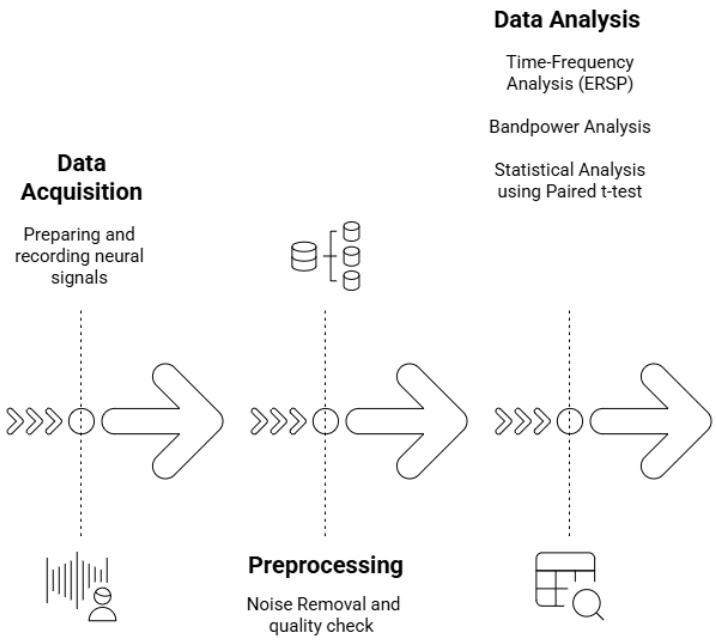


Figure 1. The study workflow. Source: Authors.

4.2. Study Design

This endeavor followed a psychophysiological approach in the analysis, while following a neurophysiological (neurological) approach in data acquisition. It employed an experimental design to investigate the neurophysiological responses of students in an educational environment to an enclosed courtyard environment. The experiment was conducted exclusively in an enclosed courtyard at the Ain Shams University Faculty of Engineering in Cairo, Egypt. To provide similar baseline conditions for cognition and emotions, all participants had EEG recordings following a two-hour standardized lecture.

The experiment aims to assess the psychological implications and outcomes of brainwave activity in relation to the courtyard environment, zeroing in on cognitive and emotional states such as tension, relaxation, and concentration. The study workflow is divided into three main stages—data acquisition, data preprocessing, and data analysis, as seen in Figure 1.

4.3. Participants

The experiment included 16 participants—9 female and 7 male—recruited from the Faculty of Engineering at Ain Shams University. According to power analysis guidelines [47] this sample size (n = 16) corresponds to a medium effect size (Cohen's d = 0.5) and provides approximately 60–70% statistical power at a 0.05 significance level (two-tailed paired t-test), which is sufficient for detecting meaningful patterns in an exploratory, controlled setting. While adequate for preliminary investigation, the limited number of participants constrains the generalizability of the results, positioning this study as a pilot that can inform future research with larger and more diverse samples.

Participants were required to be healthy individuals aged 18–22, with no history of heart conditions (e.g., arrhythmia), emotional health disorders (e.g., severe depression or post-traumatic stress disorder), neurological conditions, or vision impairments not correctable to normal. To maintain data integrity, individuals did not use medications affecting brainwave activity or the nervous system. Participants were instructed to abstain from consuming stimulants, including caffeine and tobacco, on the day of testing.

Ethical approval was granted by the Ain Shams University institutional review board, and informed consent was obtained from all participants. All were enrolled in the Urban Design Department's landscape design courses, ensuring both relevance to their academic background and commitment to the experimental study. Participants were unfamiliar with the setting in this space and, hence, have no negative experience about this space in order to minimize potential bias from prior experience. Additionally, as this was their first exposure to EEG within a research context, their responses were uninfluenced by previous procedural familiarity, though their engineering training likely enhanced their sensitivity to spatial configurations due to prior experience in design and spatial analysis.

4.4. Data Acquisition: Neurophysiological Approach

As shown in Figure 2, the recorded brain activity is categorized into distinct frequency bands, each corresponding to a specific range of brainwave frequencies. Theta (θ) was one of the brainwave frequencies that was recorded in the experiment. This frequency ranges from 4 to 8 Hz and is predominantly observed during sleep and daydreaming. It enables the individual to disconnect from the external environment, which, in turn, facilitates the acquisition of knowledge [48,49]. Alpha (α) waves, which span the Beta and Theta bands ranging from 8 to 12 Hz, are indicative of the brain's quiescent state. These waves facilitate learning, body integration, mental coordination, alertness, and tranquility [50]. Beta (β) waves are low-amplitude, high-frequency waves that range from 12 to 25 Hz; they are associated with logical thinking, anxiety, task-oriented activities, conscious thought, and active concentration. Emotiv SDK further separates low-Beta (12–18 Hz) and high-Beta (18–25 Hz) sub-bands in order to improve intensity and output precision [33,51]. With a frequency range of 25 to 100 Hz, Gamma (γ) waves are the fastest brainwaves and are associated with cognitive functioning and high-level processing tasks. They facilitate quick and effective information transfer, which is essential for learning and information processing.

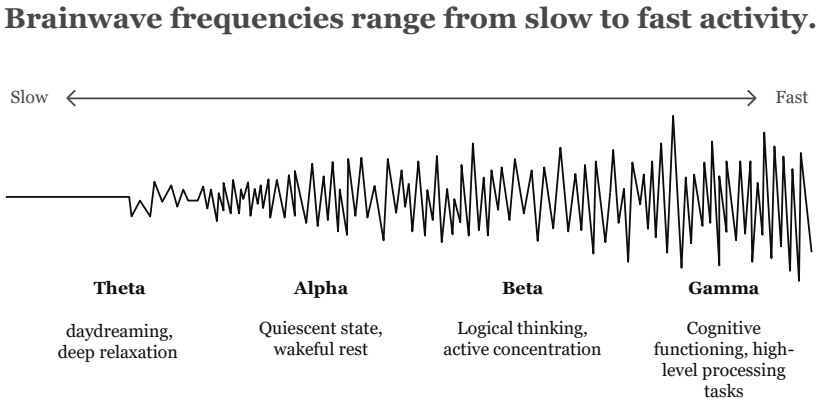


Figure 2. Brainwave frequencies. Source: Authors.

4.4.1. Apparatus Calibration and Data Preprocessing

The experiment employed the NeuroSky MindWave Mobile 2, which is a consumer-grade, single-channel, wireless EEG headset intended for non-invasive brainwave monitoring. It is characterized by a lightweight design and incorporates a dry electrode located at FP1 (forehead above the eye), along with reference and ground electrodes on an ear clip. This device was chosen for its affordability and accessibility, making it ideal for a pilot study with a limited sample. Its prior use in environmental psychology studies [33,52,53] further validates its reliability for detecting preliminary neurophysiological patterns in real-world settings. It utilizes the ThinkGear ASIC Module (TGAM) for signal processing, effectively filtering noise including EMG and 50/60 Hz interference, as well as providing raw EEG data (3–100 Hz, 512 Hz sampling rate), power spectra (Delta, Theta, Alpha, Beta, and Gamma), and eSense metrics (attention and meditation). Accurate signal capture in outdoor settings was guaranteed by the NeuroSky MindWave Mobile 2's calibration. To reduce impedance, the forehead and earlobe were cleaned with alcohol wipes before the EEG electrode was positioned at FP1; this was carried out according to the catalog of the tool. The signal quality was then evaluated using OpenViBE 3.0.0software via the ThinkGear Connector, which confirmed stability (e.g., noise levels below 15%, usually indicating an acceptable range at 12.5%) and required modifications to obtain a green status. Artifact control was attained by regulated participant movements (e.g., blinking and head tilting), with OpenViBE employing a bandpass filter (0.5–45 Hz) to eliminate high-frequency noise and low-frequency drift, thereby augmenting TGAM's filtering, as corroborated by visualization tools.

4.4.2. Procedures Seen in Figure 3

A neurophysiological (neurological) approach was utilized for data collection. The headset was positioned to capture the previously mentioned frequency bands, providing psychological interpretations, respectively [53]. To normalize cognitive load and fatigue levels, each participant underwent a 5-min EEG recording session in the enclosed courtyard immediately following a two-hour lecture. Participants were directed to sit comfortably for four minutes following a one-minute baseline recording with their eyes closed to ascertain resting brainwave activity. They engaged in a passive observation activity, concentrating on their environment without undertaking cognitively taxing activities. A passive observation task was chosen to isolate neurophysiological responses to environmental qualities, sensory perception, and spatial atmosphere, aligning with neurolandscape research focused on baseline mental states in response to mere landscape features.

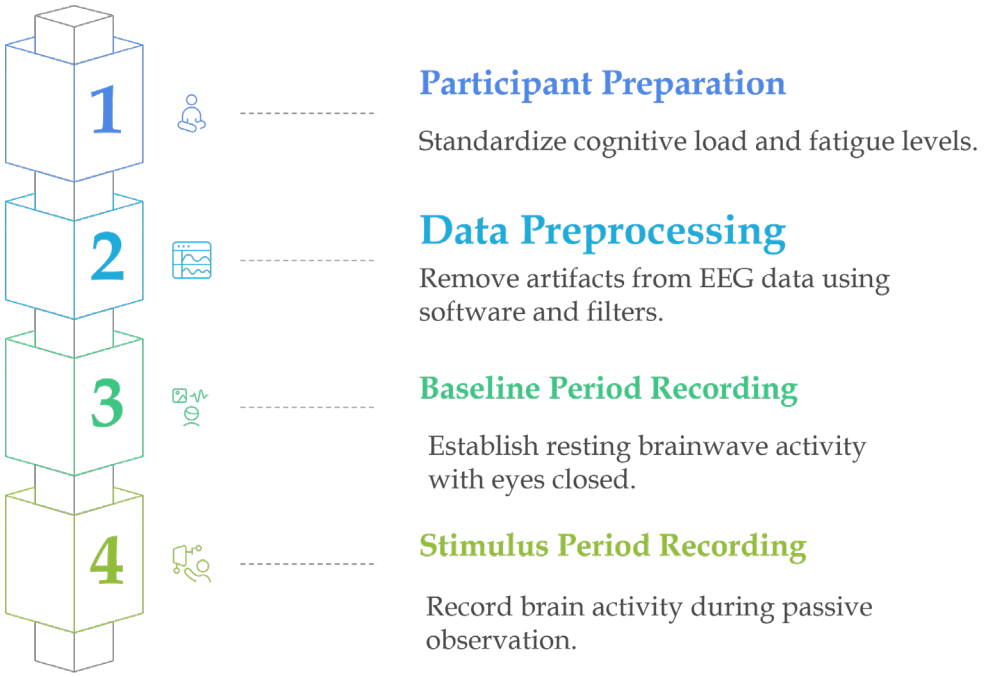


Figure 3. Experiment procedures. Source: Authors.

4.5. Data Processing and Analysis: Psychophysiological Approach (Figure 4)

4.5.1. Data Analyses

A psychophysiological approach was adopted to analyze EEG data, interpreting brainwave activity to assess psychological states. Neural activity to the courtyard environment was evaluated by three tandem analyses. The full analysis workflow began with raw EEG data being collected via NeuroSky MindWave Mobile 2, followed by preprocessing in EEGLAB to remove artifacts (e.g., noise from muscle movement), feature extraction using time–frequency and band power methods, and statistical comparison to identify significant changes. Firstly, a time–frequency analysis was conducted, leveraging EEGLAB in MATLAB (https://eeglab.ucsd.edu/, accessed on 20 March 2025). The power of each band was quantified using Power Spectral Density (PSD) over a 4 min stimulus interval. Individual variability was assessed using a 1 min baseline with eyes closed. This analysis produced Event-Related Spectral Perturbation (ERSP) graphs that visualize individual event-related changes in spectral power across time and frequency, identifying transient neural responses to the courtyard environment and how the mental state of each participant changed from the baseline state to the stimuli state.

Secondly, a band power analysis utilizing Epoch-Based Power Distribution was conducted using MATLAB, aimed at quantifying the mean power within specific frequency bands to assess sustained changes in brain activity during the stimulus period.

This analysis computed mean band power percentages across seven frequency bands (theta, low alpha, high alpha, low beta, high beta, low gamma, and mid gamma) for the baseline (0–60 s) and stimulus (60–300 s) periods. Individual responses and inter-band correlations were visualized using the corr function with pairwise deletion, and changes were computed as the difference between means.

Thirdly, inferential analysis utilized paired *t*-tests to statistically validate band power differences, complementing the descriptive insights from ERSP and band power by confirming whether observed changes are unlikely due to chance. The paired *t*-test was justified based on its suitability for within-subject designs through analyzing repeated measures within the same participants, comparing baseline vs. stimulus conditions.

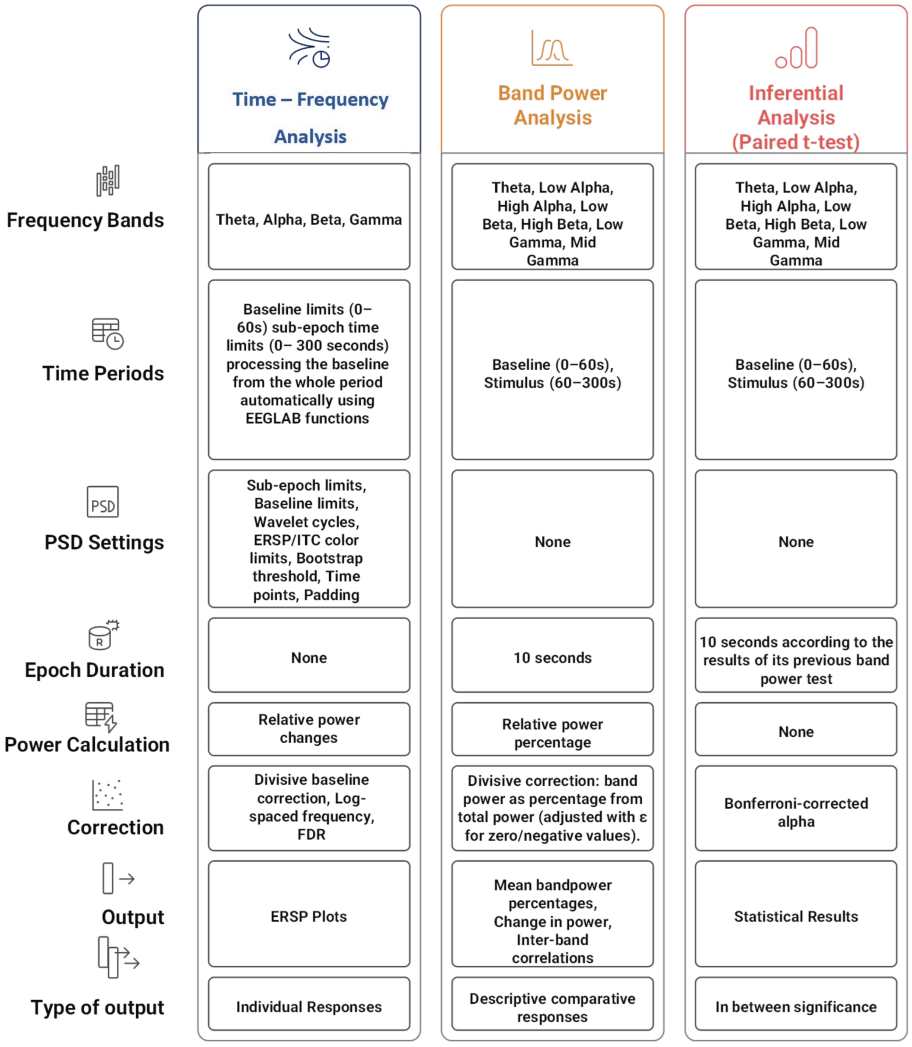


Figure 4. Data analysis and data processing. Source: Authors.

The paired *t*-test was performed with a Bonferroni-corrected significance threshold of $\alpha = 0.0071$, reflecting correction for multiple comparisons across seven frequency bands. Typically, in a test like the paired *t*-test, a result is "significant" if the *p*-value is less than 0.05 (5% chance that it is random). However, when attempting many things at once (like a set of bands: Theta, Low Alpha, etc.), it might accidentally generate some "significant" results by chance. The Bonferroni correction adjusts this threshold to make it harder to call something significant, reducing those false positives. It does this by dividing the usual 0.05 by the number of tests ($0.05 \div 7 = 0.0071$). Thus, with $\alpha = 0.0071$, a *p*-value would need to be less than 0.0071 to be significant, not just 0.05. This was implemented on the aggregated change scores (validChange = validStimulus − validBaseline) of the band power data, which provided statistical outcomes such as *p*-values, test decisions, t-statistics, and confidence intervals. Furthermore, prior to paired *t*-tests, Shapiro–Wilk tests confirmed that the band power change scores (stimulus − baseline) for all frequency bands were normally distributed. Given the small sample size ($n = 16$), non-parametric Wilcoxon signed-rank tests were also conducted as a robustness check; the results aligned with the t-test conclusion.

4.5.2. Data Processing

EEGLAB in MATLAB and its fundamental functions were used to process the EEG data from 16 subjects. Power Spectral Density (PSD) was used in the time–frequency

analysis in EEGLAB, with parameters including sub-epoch time limits (0–300 s), frequency limits per band, baseline limits (0–60 s), wavelet cycles (3–0.8), ERSP color limits (20), ITC color limits (0.5), and a bootstrap significance threshold of 0.01. This encompassed 200 time points, with a padding of 1, as well as a divisive baseline correction to handle multiplicative noise, preserve relative signal changes, and stabilize variance when baseline fluctuations scale with signal magnitude. It also utilizes log-spaced frequency representation and applies False Discovery Rate (FDR) correction as necessary, with an initial emphasis on Theta, Alpha, Beta, and Gamma bands. Then, continuous EEG recordings were imported from Excel files via MATLAB, with detailed band power values (Theta: 4–8 Hz, LowAlpha: 8–10 Hz, HighAlpha: 10–12 Hz, LowBeta: 12–20 Hz, HighBeta: 20–25 Hz, LowGamma: 25–30 Hz, MidGamma: 30–40 Hz) adjusted to non-negative values to reduce erroneous readings. Also, the data were divided into 10 s epochs according to a sampling frequency calculated from inter-sample time intervals, with baseline epochs ranging from 0 to 60 s and stimulation epochs extending from 60 to 300 s. For each epoch, the relative power contribution of each band was computed as a percentage of the total power to standardize power across frequency bands, mitigating division-by-zero mistakes by assigning zero or negative values to a minimal threshold (ε). The mean band power was calculated over valid epochs for both periods, and the change in power was assessed as the difference.

5. Results and Discussion

5.1. Time–Frequency Analysis (ERSP)

Time–frequency analysis was conducted on EEG data from 16 participants (P1–P9: female; P10–P16: male) to evaluate neural responses in the Theta, Alpha, and Beta frequency bands during a five-minute passive observation task in an enclosed courtyard. Event-Related Spectral Perturbation (ERSP) plots were generated to quantify spectral power changes, expressed in decibels (dB), relative to a pre-stimulus baseline, over a nominal time range of 0 to 3 units, where the time axis is scaled by a factor of 10^5 milliseconds. This scaling implies that the ERSP horizontal axis spans from 0×10^5 ms = 0 ms to 3×10^5 ms = 300,000 ms, corresponding to a real-time duration of 0 to 5 min. In these plots, green regions (~0 dB) indicate baseline stability, red/orange areas (+10 to +20 dB) reflect increased neural activity, and blue areas (-10 to -20 dB) denote reduced activity, with extreme values reaching beyond these ranges. The dB scale provides a standardized measure of power variation relative to baseline, facilitating the interpretation of neural modulation patterns. The subsequent Figure 5 presents the band-specific ERSP findings for each participant.

Theta band (4–8 Hz)

Green dominates, indicating stable power (around 0 dB) for most participants. P2, P6, P5 (all female), and P14 (male) show occasional blue (-10 to -20 dB) decreases, suggesting disengagement, while P3 and P9 (both female) show sporadic red/yellow (+10 to +20 dB) increases, indicating enhanced relaxation. P16, P11, P15, P13 (all male), and P12 (male) exhibit frequent red/yellow colors, reflecting large increases in relaxation-related activity, with P8 (female) showing a mix of decreases and more pronounced increases.

Alpha Band (8–12 Hz)

The predominant green (0 dB) signifies stability in relevance to the baseline period. Random blue (-10 to -20 dB) color decreases for P1, P4, P7 (all female), and P10 (male), suggesting disengagement, while rare red/yellow colors (+10 to +20 dB) increase for P2, P5 (both female), P8 (female), and P11 (male), indicating mild alertness. Frequent red/yellow for P14 (male) shows increased engagement, with P16 (male) displaying constant red/yellow, reflecting a significant shift from baseline idleness.

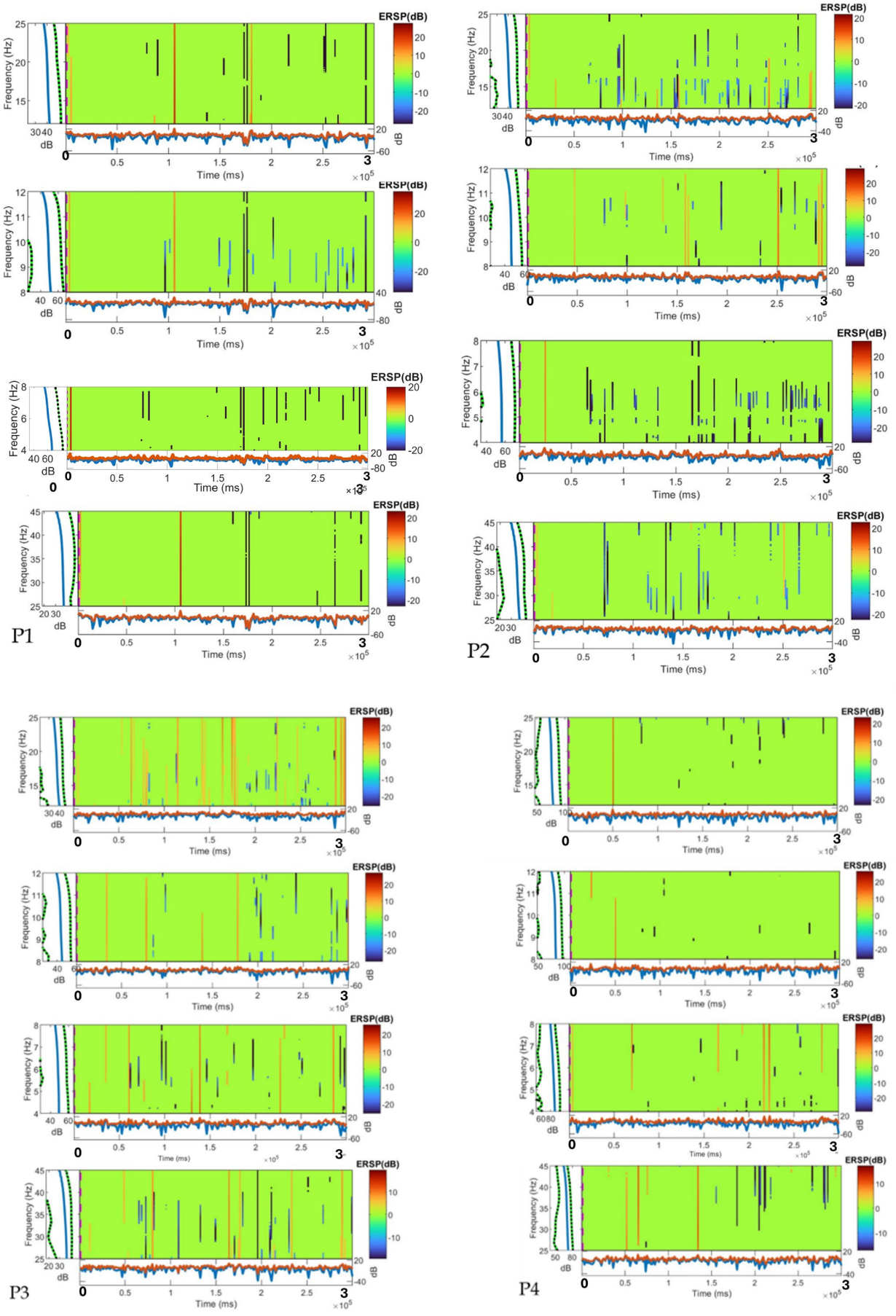


Figure 5. *Cont.*

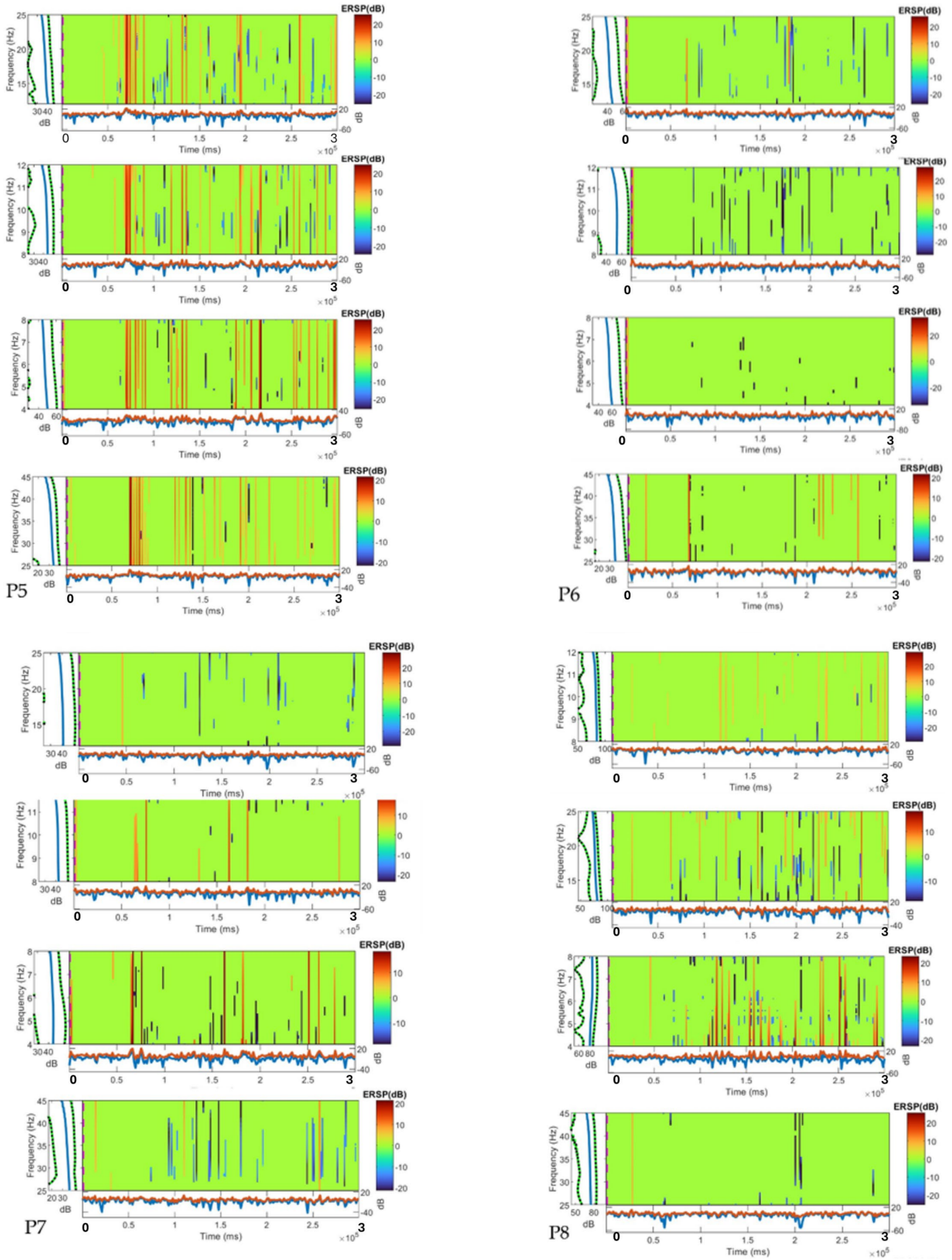


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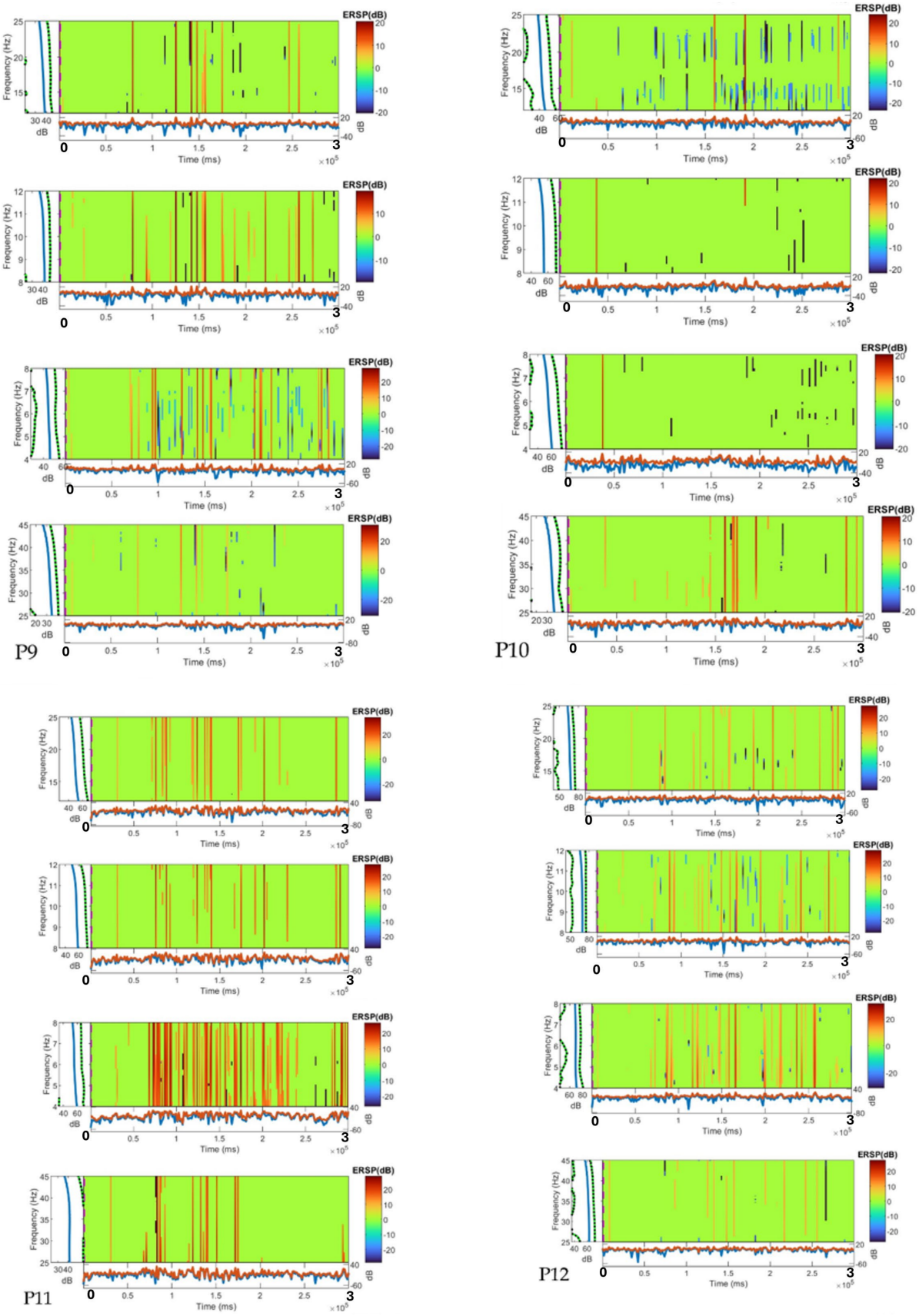


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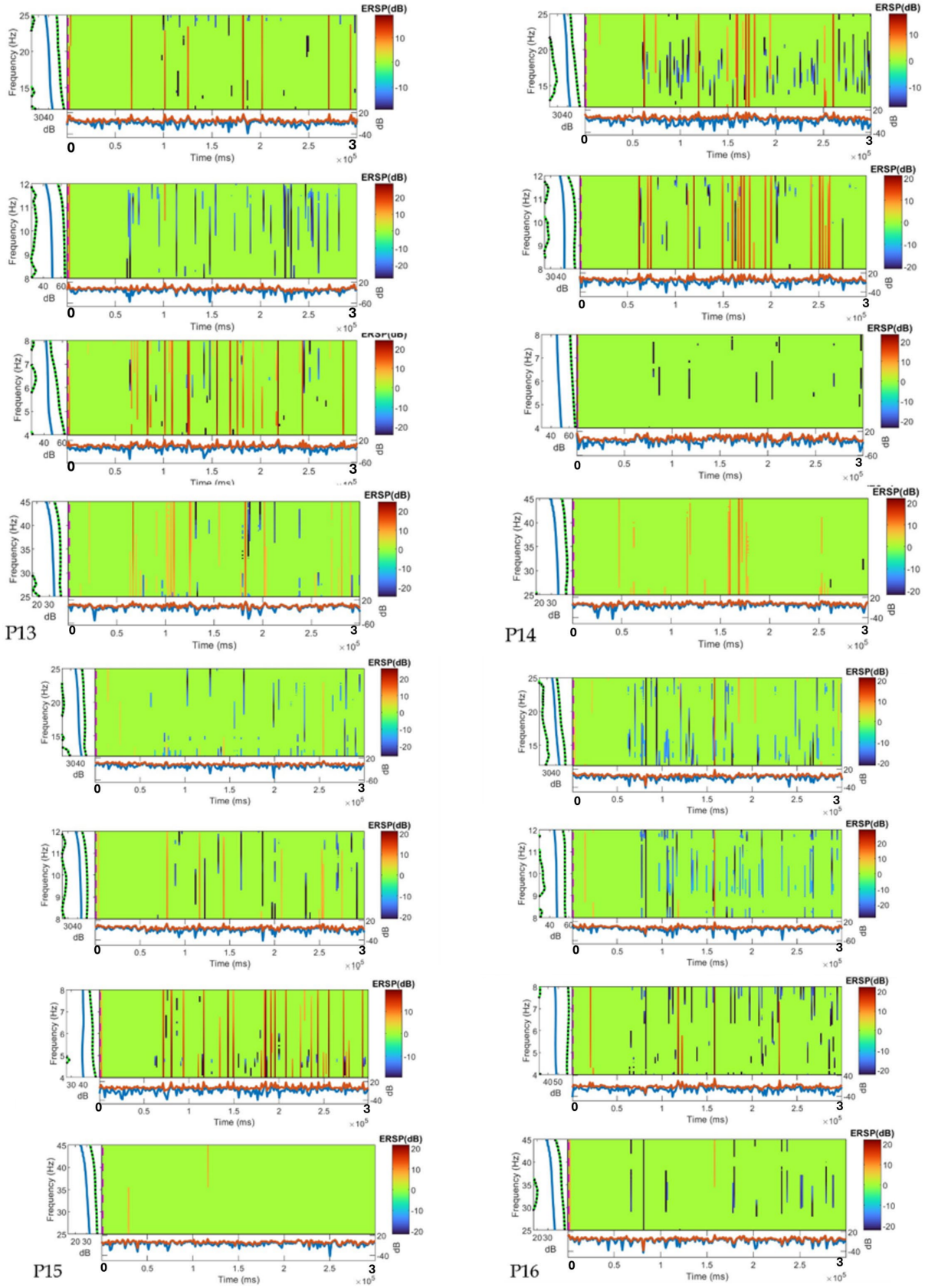


Figure 5. Band power analyses of 16 participants. Source: Authors, using EEGLAB in MATLAB.

Beta Band (12–25 Hz)

Green prevalence (0 dB) indicates stability relative to the baseline. P3, P6, P9 (all female), P12, and P15 (both male) show sporadic blue (−10 to −20 dB) decreases, suggesting reduced focus, while P1, P4, P7 (all female), P10, P13 (both male), and P16 (male) exhibit sporadic to intense red/yellow (+10 to +20 dB) increases, indicating attention peaks, with P16 showing the strongest and most frequent red/yellow, linked to heightened cognitive processing.

Gamma Band (25–45 Hz)

Green remains prevalent (0 dB), reflecting stability relative to the baseline. P4, P7 (both female), P10, P13 (both male), and P16 (male) show occasional red/yellow (+10 to +20 dB) increases, particularly at 20–25 Hz, suggesting cognitive engagement, while P16 has the most uniform and highest red/yellow color, indicating large power increases. P3, P6, P9 (all female), and P12 (male) have more frequent blue (−10 to −20 dB) decreases, with slight increases over time, and P15 (male) shows predominately green fields, maintaining a stable state.

Overall patterns and trends

Overall, the Event-Related Spectral Perturbation (ERSP) analysis revealed distinct neural modulation patterns across the Theta, Alpha, Beta, and Gamma bands during the five-minute observation period. In the Theta band, several participants exhibited moderate-to-pronounced increases in spectral power, suggesting enhanced relaxation and restorative processing, whereas others showed minimal change from baseline. Alpha band activity displayed mixed patterns, with some participants showing increased synchronization—indicative of calm attentional states—while others demonstrated reductions, potentially reflecting higher sensory engagement. Beta band responses varied, with localized power increases suggesting moments of focused attention and cognitive engagement, as well as decreases corresponding to reduced task-related processing. Gamma band changes were less consistent, with occasional bursts in high-frequency activity that may be linked to brief episodes of heightened perceptual or cognitive integration. These variations underline both the influence of courtyard design features on neural activity and individual differences in environmental perception.

For participants such as P1, where all bands show green, this stability relative to the baseline suggests that the participant maintained their initial neural state—potentially a neutral or undisturbed condition. As shown in Figure 6, these trends, illustrated with green (increases), gray (stable), and red (decreases), underscore neural response heterogeneity, potentially influenced by courtyard features or gender differences, warranting further investigation.

Furthermore, in Figure 7, a composite pie chart merges EEG power modulation across all frequency bands (Theta 4–8 Hz, Alpha 8–12 Hz, Beta 12–25 Hz, and Gamma 25–45 Hz) for the 16 participants (P1–P9: female; P10–P16: male; aged 18–24). An analysis of 64 band-specific observations revealed 37.5% increases (e.g., P16, P13 (both male), and P3 (female)), 26.6% decreases (e.g., P2, P6, and P5 (all female)), and 35.9% stability (e.g., P1, P4, and P8 (all female)), based on ERSP data comparing the first minute to the subsequent four minutes. This division, with green indicating increases (+10 to +20 dB), red denoting decreases (−10 to −20 dB), and gray signifying stability (0 dB relative to the baseline), reflects a balanced neural activation profile. P16's (male) consistent increases suggest high reactivity, possibly influenced by the courtyard environment or gender-specific responses, while stable cases like P1 (female) across bands indicate preserving the baseline state, potentially reflecting an adaptive response to the courtyard. However, the psychological interpretation depends on the baseline condition, which requires further characterization, underscoring the need for multi-relational EEG analyses.

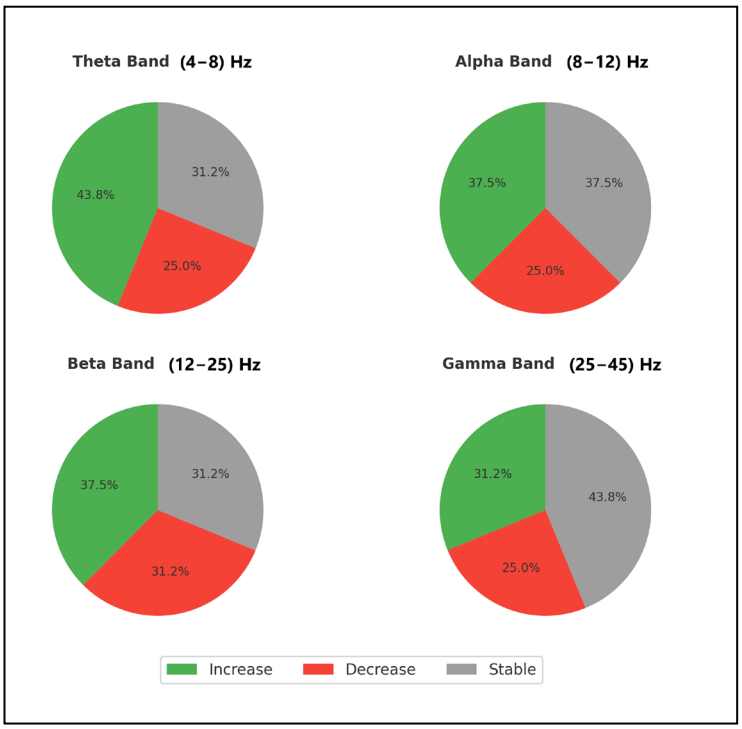


Figure 6. Event-Related Spectral Perturbation (ERSP) analysis of EEG responses across all bands for 16 participants (P1–P9: female; P10–P16: male) after baseline correction. Source: Authors.

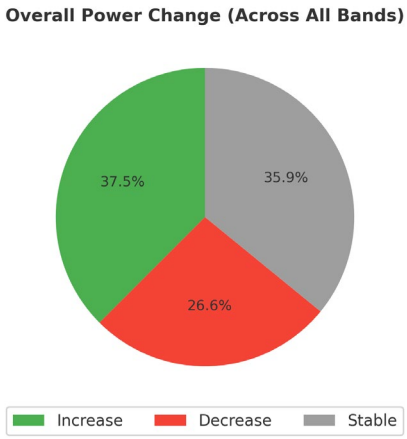


Figure 7. Composite pie chart of EEG power modulation across all bands for 16 participants after baseline correction. Source: Authors.

Lastly, a participant profile was developed from the EEG data analysis, summarizing individual power variations across the designated frequency bands (Table 5). Sensitivity levels were classified based on EEG response patterns—high sensitivity indicated frequent and pronounced fluctuations, moderate sensitivity reflected occasional but consistent changes, and low sensitivity denoted predominantly stable activity.

Table 5. Participant profiles.

ID	Gender	Experience	Sensitivity	Theta Band	Alpha Band	Beta Band	Gamma Band
P1	Female	Unfamiliar with courtyard; no EEG experience	Moderate	Stable	Random decreases (disengagement)	Sporadic-to-intense increases (attention peaks)	Stable
P2	Female	Unfamiliar with courtyard; no EEG experience	High	Occasional decreases (disengagement)	Rare increases (mild alertness)	Stable	Stable

Table 5. *Cont.*

ID	Gender	Experience	Sensitivity	Theta Band	Alpha Band	Beta Band	Gamma Band
P3	Female	Unfamiliar with courtyard; no EEG experience	Low	Sporadic increases (enhanced relaxation)	Stable	Sporadic decreases (reduced focus)	Frequent decreases; slight increases
P4	Female	Unfamiliar with courtyard; no EEG experience	Moderate	Stable	Random decreases (disengagement)	Sporadic-to-intense increases (attention peaks)	Occasional increases (cognitive engagement)
P5	Female	Unfamiliar with courtyard; no EEG experience	High	Occasional decreases (disengagement)	Rare increases (mild alertness)	Stable	Stable
P6	Female	Unfamiliar with courtyard; no EEG experience	Low	Occasional decreases (disengagement)	Stable	Sporadic decreases (reduced focus)	Frequent decreases; slight increases
P7	Female	Unfamiliar with courtyard; no EEG experience	Moderate	Stable	Random decreases (disengagement)	Sporadic-to-intense increases (attention peaks)	Occasional increases (cognitive engagement)
P8	Female	Unfamiliar with courtyard; no EEG experience	High	Mix of decreases and pronounced increases (relaxation)	Rare increases (mild alertness)	Stable	Stable
P9	Female	Unfamiliar with courtyard; no EEG experience	Low	Sporadic increases (enhanced relaxation)	Stable	Sporadic decreases (reduced focus)	Frequent decreases; slight increases
P10	Male	Unfamiliar with courtyard; no EEG experience	Moderate	Stable	Random decreases (disengagement)	Sporadic-to-intense increases (attention peaks)	Occasional increases (cognitive engagement)
P11	Male	Unfamiliar with courtyard; no EEG experience	Low	Frequent increases (large relaxation)	Rare increases (mild alertness)	Stable	Stable
P12	Male	Unfamiliar with courtyard; no EEG experience	High	Frequent increases (large relaxation)	Stable	Sporadic decreases (reduced focus)	Frequent decreases; slight increases
P13	Male	Unfamiliar with courtyard; no EEG experience	Moderate	Frequent increases (large relaxation)	Stable	Sporadic-to-intense increases (attention peaks)	Occasional increases (cognitive engagement)
P14	Male	Unfamiliar with courtyard; no EEG experience	High	Occasional decreases (disengagement)	Frequent increases (increased engagement)	Stable	Stable
P15	Male	Unfamiliar with courtyard; no EEG experience	Low	Frequent increases (large relaxation)	Stable	Sporadic decreases (reduced focus)	Predominantly stable
P16	Male	Unfamiliar with courtyard; no EEG experience	Moderate	Frequent increases (large relaxation)	Constant increases (significant engagement)	Strong, frequent increases (heightened cognitive processing)	Uniform, high increases (cognitive engagement)

Source: Authors.

5.2. Band Power Descriptive Analysis

An epoch-by-epoch power distribution analysis was conducted to compare the relative proportions of EEG band power between two time periods—a 1 min baseline and a 4 min exposure to the stimulus. The analysis comprised the following four components: (1) mean band power comparison across the two experimental conditions; (2) assessment of the **distribution of changes;** (3) examination of **individual response patterns**; and (4) evaluation of **band change correlations**. The results of these analyses are presented in the following graphs.

1. Mean Band power Comparison (Figure 8): This bar chart compares the mean power (%) across different brain frequency bands (Theta, LowAlpha, HighAlpha, LowBeta,

HighBeta, LowGamma, MidGamma) under two conditions—baseline (blue bars) and stimulus (orange bars). Theta and LowAlpha show the highest power, with stimulus slightly increasing power in Theta and decreasing it in LowAlpha and HighAlpha compared to baseline.

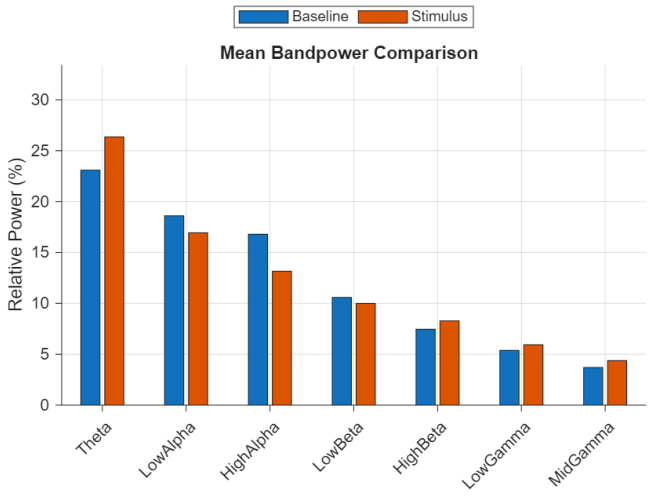


Figure 8. Mean band power analysis. Source: Authors.

2. Distribution of Changes (Figure 9): This box plot shows the distribution of percentage changes in power for each frequency band. The median changes are close to zero, with Theta and LowAlpha showing the widest distributions (both positive and negative outliers), while MidGamma has a narrower range and a slight positive shift.

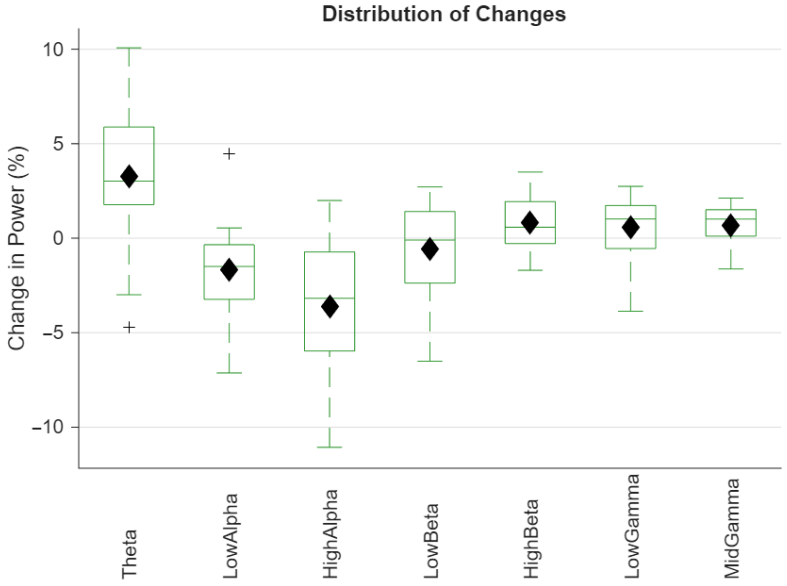


Figure 9. Distribution of changes. Source: Authors.

3. Individual Responses (Figure 10): This line graph displays the percentage change in power for each frequency band (Theta to MidGamma) across multiple individual responses (different colored lines). The changes vary widely, with some bands (e.g., HighAlpha) showing significant decreases, while others (e.g., LowGamma) show more stability.

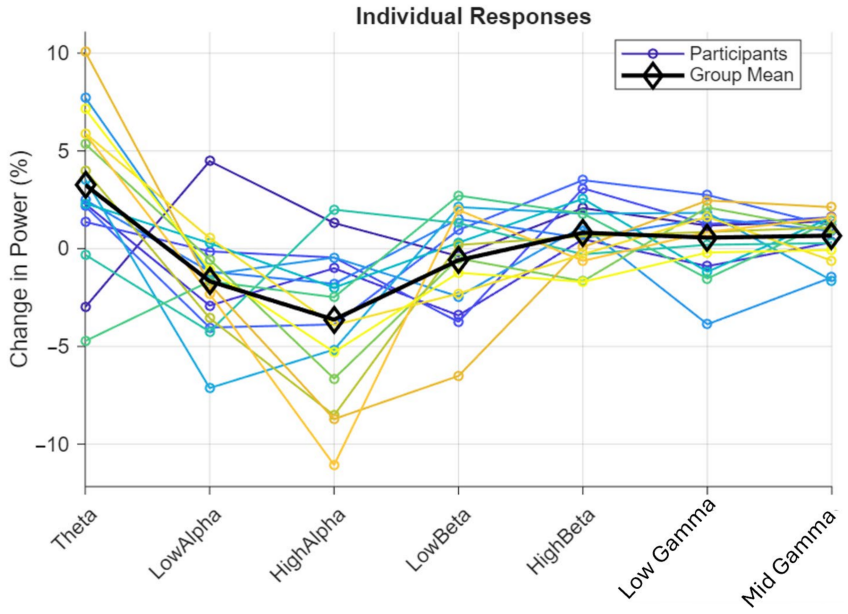


Figure 10. Individual responses. Source: Authors.

4. Band Change Correlations (Figure 11): The correlation matrix illustrates the pairwise relationships between stimulus-induced power changes across EEG frequency bands in the study cohort. In this visualization, red indicates positive correlations (0 to +1), signifying that power changes in paired bands co-vary in the same direction, while blue denotes negative correlations (−1 to 0), reflecting inverse relationships where power increases in one band associated with decreases in another. The dark-red diagonal confirms the expected perfect positive autocorrelations (r = +1) for each band. For example, dark-blue, where "LowAlpha" meets "Theta," means that participants who showed increased Low Alpha waves during the stimulus also tended to show decreased Theta waves. The asterisks (*) mark correlations that are statistically significant (less than 5% likely to occur by chance).

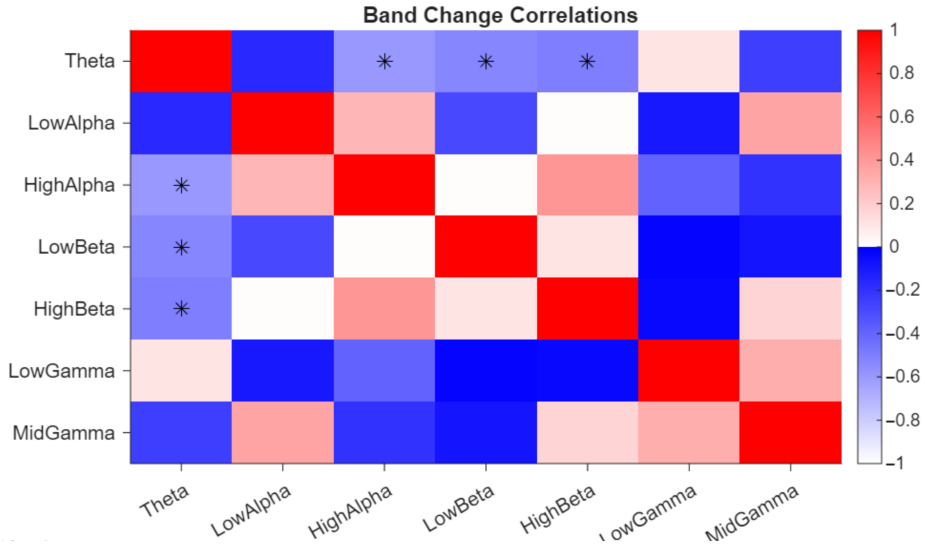


Figure 11. Band change correlations. Source: Authors.

For a deeper analysis, the results are presented numerically in the following table (Table 6). The mean relative power (%) is provided for each frequency band (Theta, Low Alpha, High Alpha, Low Beta, High Beta, Low Gamma, and Mid Gamma). The final

row displays the mean power difference (Δ%) between the stimulus and baseline periods to ascertain whether neural activity patterns are either enhanced or suppressed during stimulation in comparison to rest.

Table 6. Band power analysis.

Band Power Analysis with Epoch-Based Power Distribution	Theta	Low Alpha	High Alpha	Low Beta	High Beta	Low Gamma	Mid Gamma
Baseline Period (1 min) Mean (%)	23.088	18.60	16.787	10.583	7.462	5.3742	3.7035
Stimulus Period (4 min) Mean (%)	26.353	16.94	13.158	9.993	8.280	5.9377	4.3703
Change (Stimulus–Baseline) Mean Δ (%)	+3.265	−1.666	−3.630	−0.59	+0.81	0.5635	0.6667

Source: Authors, based on MATLAB code results.

Gamma↑ (↑0.56–0.67%) + High Beta ↑ (↑0.82%) Combination

The intricacies of the courtyard, such as the texture of the vegetation in an enclosed environment and natural sounds, were being processed through the eyes, as indicated by a slow increase in Gamma activity (0.56–0.67%). According to [16,44], the slow Gamma rise is indicative of a limited engagement that skips cognitive surplus, as indicated by a slight spike in high Beta activity (↑0.82%). That is, participants were actively engaging with the intricate details of the environment.

Eyes-Closed Baseline (High Alpha)

In the eyes-closed condition, subjects displayed high-amplitude Alpha waves, signifying coordinated activity in the visual cortex, aligning with a default resting state marked by limited visual processing. This baseline functioned as a reference for subsequent alterations following exposure to the courtyard.

Eyes-Opened Stimulus (Alpha Decrease)

Upon opening their eyes, there was an immediate desynchronization of Alpha waves, indicative of the visual cortex's interaction with exterior stimuli. The extent of Alpha suppression was quantified at −3.63%. However, this result was presumably influenced by the physiological stimulation of visual processing and further cognitive involvement with the courtyard's surroundings, encompassing diverse leaf patterns, tree canopies, and birds sounds; this could be due to the Alpha blockage effect [12].

Theta ↑ + Alpha ↓ Combination

The analysis revealed a significant increase in Theta activity (+3.27%) alongside the Alpha decrease. Typically, Theta remains stable when Alpha suppression results solely from eyes opening.

These paradoxical findings have two interpretations.

Theta rise measures passive restoration, and Alpha reduction measures mild cognitive activation and lower relaxation states, balancing with nature through the presence of courtyard stimuli (e.g., leaf rustles and wind sounds) [54]. It aligns with **nature's "soft fascination,"** in which the natural features of the courtyard, like dense vegetation and quiet atmosphere in a bounded away place, had a low mental load despite active visual attention.

As such, according to [54,55], nature's **"Soft Fascination"** concept reflects Attention Restoration Theory (ART). The realm of the courtyard captures attention readily without straining cognitive effort. The increase in Theta indicated that the landscape brought about a restoration state, reducing mental exhaustion and promoting relaxation while the participants were visually engaged with the prospect.

On the other hand, the decrease in Alpha power when opening the eyes is not obligatory but is a well-documented phenomenon under specific conditions. Research indicates

that Alpha activity (8–12 Hz), which is associated with a resting state, typically diminishes with eyes-open compared to eyes-closed states due to increased visual input and attentional demand, which is known as **alpha blocking,** even if the scene was not natural or demanding visual engagement. However, this effect varies with context, e.g., in a highly relaxing or monotonous environment, Alpha may remain stable or increase slightly, especially if the task minimizes cognitive load.

To investigate if the findings yielded are because of nature's soft fascination or the Alpha blocking effect, the authors adopted an approach in which they removed the initial 10 s epoch of the 4 min stimulus time from analysis. This modification was used to check if the eye-open effect during the first epoch might have caused any bias in the result for the whole stimulus period, in that it may have produced a dramatic drop in Alpha power, affecting the mean value. However, when the first epoch was removed, the results also maintained similar trends, thus showing that soft fascination and restorative attention, which comprise engagement without overstimulation, are the primary effects. The following table shows the results after the 10 s epoch was removed (Table 7).

Table 7. Band power analysis-adjusted epochs.

Period	Theta (%)	Low Alpha (%)	High Alpha (%)	Low Beta (%)	High Beta (%)	Low Gamma (%)	Mid Gamma (%)
Baseline (1 Min)	23.088	18.607	16.787	10.583	7.4618	5.3742	3.7035
Stimulus (70–240s)	26.455	16.905	13.086	9.9942	8.243	5.9248	4.4565
Change (Δ)	+3.3673	−1.7014	−3.7016	−0.58925	+0.78115	+0.55065	+0.75305

Source: Authors, using Matlab code.

5.3. Inferential Statistical Analysis

Inferential tests (paired *t*-tests with Bonferroni-corrected alpha = 0.0071) are utilized to assess changes between baseline (0–60 s) and stimulus (60–240 s) periods upon statistical analysis.

Paired *t*-test Results (Bonferroni-corrected $\alpha = 0.0071$)

- Theta: $p = 0.0041$, h = 1, t(15) = 3.3868, 95% CI = [0.2651, 6.2650]—significant increase, indicating a reliable shift toward relaxation.
- LowAlpha: $p = 0.0200$, h = 0, t(15) = −2.6031, 95% CI = [−3.6581, 0.3257]—not significant, suggesting no reliable change.
- HighAlpha: $p = 0.0015$, h = 1, t(15) = −3.8814, 95% CI = [−6.5399, −0.7197]—significant decrease, possibly reflecting a shift from resting to engaged states.
- LowBeta: $p = 0.3662$, h = 0, t(15) = −0.9318, 95% CI = [−2.5640, 1.3823]—not significant, indicating stable activity.
- HighBeta: $p = 0.0538$, h = 0, t(15) = 2.0927, 95% CI = [−0.3985, 2.0353]—not significant, though near threshold, suggesting possible mild engagement.
- LowGamma: $p = 0.2147$, h = 0, t(15) = 1.2957, 95% CI = [−0.7899, 1.9169]—not significant.
- MidGamma: $p = 0.0303$, h = 0, t(15) = 2.3924, 95% CI = [−0.2005, 1.5341]—close to significant ($p = 0.0303$), hinting at possible sensory engagement.

Only Theta and High Alpha alterations are still significant after Bonferroni correction, suggesting a strong neural modulation of relaxation (Theta increase) and shift away from resting states (high Alpha decrease) under the exposure to courtyards.

Psychological Implications

The significant Theta increase (+3.27%, $p = 0.0041$, below Bonferroni-corrected $\alpha = 0.0071$) suggests enhanced restoration or mental withdrawal, supporting the courtyard's role as a restorative space; this aligns with theta activity (4–8 Hz) being associated

with meditative states and reduced cognitive load during passive tasks [56]. In contrast, the significant high Alpha decrease (−3.63%, $p = 0.0015$) indicates a shift toward increased alertness or engagement. Together, these findings highlight the courtyard's dual influence, promoting relaxation while occasionally stimulating attention.

6. Multimodal EEG Analysis: Findings and Synthesis

The paired *t*-test and band power descriptive analysis are equivalent to signaling the same results of significant Theta increase and significant high Alpha reduction. Individual differences also indicate the same trends, as ERSP data show, for instance, P3 and P5 with significant Theta increases of +10 to +15 dB, as well as P1 and P7 with high Alpha reductions. This is a sharp contrast, in that Alpha power would have been expected to increase in passive, relaxed states—particularly under the courtyard setting designed to induce relaxation. As in this research, previous EEG studies have demonstrated that exposure to natural environments is linked to a variety of neurophysiological patterns that are associated with stress reduction. These patterns include an increase in Alpha [57–62] and Theta power [62], as well as a decrease in Beta activity [58]. However, in this endeavor, it is seen that Alpha shows significant decreases, reflecting soft fascination after the removal of the first epoch, which means a continued Alpha blocking effect across the 4 min of visual stimuli.

To grasp these psychological implications, the authors referred to a previous study [63] that was conducted to compare the effect of walking through urban green areas, urban quiet areas, and urban busy areas. The results also show a higher Alpha increase in urban busy areas, while Alpha decreased in urban quiet areas, which is unexpected. But the study triggers an insight suggesting that the familiarity of the busy urban setting (e.g., familiar shops and landmarks like bus stops) may have driven the increase in Alpha, as familiar environments are associated with higher Alpha power [64]. In contrast, the urban quiet setting, being less familiar (e.g., a less-visited street), may have induced fascination (a core ART component), engaged involuntary attention, and potentially suppressed Alpha activity. In accordance with this study, the inclusion criteria of students were primarily determined by their unfamiliarity with the courtyard, resulting in a gentle fascination effect rather than any other effect. This elucidates a future research scope regarding the potential impact of familiarity as a concept on the mental and emotional state of space users.

Additionally, prior research that has demonstrated an increase in Alpha has concentrated on the comparison between urban and natural environments. Nevertheless, this study addresses the presence of specific natural elements in an enclosed outdoor space within an urban environment. Consequently, the concept is more closely tied to the extent to which Alpha has increased or decreased. Additionally, the suppression of Alpha was less than 5%. This contrasts with urban environments, which typically exhibit Alpha suppression of over 5% [63]. Hence, the courtyard imparts a natural feeling despite its urban realm. Therefore, the role of Alpha (8–12 Hz) and mid Gamma (35–45) in our research, while not a predictor, demonstrates a suppressor effect, increasing the effect strength of Theta on the courtyard-dependent variable. This suggests that Alpha modulation in this setting is more of a response to external factors than a direct psychological state indicator, potentially confounding its use as a primary measure of relaxation or stress. Given this, Alpha's decrease aligns with attentional shifts rather than a pure relaxation metric, making it valuable for assessing engagement or environmental interaction rather than sole relaxation.

Moreover, a previous study was conducted to investigate the correlation between EEG functional connectivity and exposure to nature, in which a restorative scenario (i.e., a wooded garden) was associated with a considerable increase in Theta connectivity, in contrast to a non-restorative scenario (i.e., a traffic island) [64]. This reflects the significant

restorative impact of an enclosed space that incorporates natural sounds and features elements of landscapes, such as vegetation.

Finally, to translate the neurophysiological findings into actionable spatial guidelines, the following table (Table 8) synthesizes the observed EEG responses with specific courtyard design features, providing evidence-based recommendations for enhancing mental restoration and engagement in similar outdoor settings while considering the context-specific design.

Table 8. Design recommendations derived from EEG-based analyses of enclosed courtyard environments.

Design Aspect	Space Features	EEG Implications	Design Recommendations
Enclosure degree	Enclosed courtyard with visible sky	Enhances Theta activity (linked to psychological restoration)	Avoid overly wide/open courtyards to preserve a sense of containment and refuge.
(Height-to-width proportion)	approx. 1:1 (15 m height/~15 m width)		- Maintain H/W ratios between 0.8 and 1.2 to preserve a sense of containment while allowing openness. - For smaller courtyards (<20 m width), ensure vertical elements (facades, trellises, and pergolas) maintain perceived enclosure. - Avoid widths exceeding 1.5× height, as this reduces restorative benefits
Vegetation-to-hardscape ratio	~35% vegetation/ 65% hardscape	Sufficient to induce Theta enhancement while supporting mild cognitive engagement	- Maintain minimum 30–40% vegetation coverage. - Use multi-layered planting: canopy trees (6–8 m height), shrubs (1–2 m height), and ground covers. - Canopy coverage target: 20–25% of courtyard area. - Select species with seasonal foliage variation for visual interest. - Ensure permeable paving in at least 40% of hardscape to support microclimate.
Spatial configuration and furniture placement	Linear layout with central walkway and benches along vegetation zones	Seating near vegetation and enclosed edges aligns with increased Theta activity	- Place seating 1–2 m from vegetation for optimal visual and sensory engagement. - Orient seating toward natural focal points (trees and water features) rather than blank walls. - Use natural materials (timber and stone) for seating surfaces. - Avoid clustering benches in sterile or fully paved areas.
Acoustic and sensory design	Subtle natural stimuli (leaf rustling and wind)	Mild cognitive activation and sensory engagement: Alpha suppression, low Gamma near to significance, and restoration (Theta increase)	- Preserve natural soundscapes by maintaining vegetation corridors.
Familiarity vs. Fascination	Slightly unfamiliar courtyard layout with distinctive planting design	Novelty triggers involuntary attention (Alpha modulation)	- Incorporate at least one unique spatial element. - Limit direct axial sightlines to external streets to maintain immersion. - Avoid overuse of standard geometric plaza layouts.
Seasonal and climatic considerations	Comfortable microclimate at 22–26 °C, clear days	Thermal comfort likely enhances restoration	- Provide shade for at least 50% of seating areas during peak sun hours via canopy trees or tensile structures. - Use deciduous trees for seasonal variation and passive temperature regulation. - Include seasonal flowering plants for continuous visual stimulation.

Source: Authors.

This study adds something new to the emerging field of neurolandscape research by offering preliminary insights into the neurophysiological effects of courtyard design on mental health. As a pilot study, its goal was to find possible associations rather than draw conclusions that could be applied to other situations. Based on previous EEG studies in environmental psychology, the study's sample size of 16 participants yielded a sta-

tistical power of about 60–70% to detect medium effect sizes (Cohen's d = 0.5, $\alpha = 0.05$, two-tailed paired *t*-test). This sample size and the single-site design, which was carried out at a particular Ain Shams University courtyard, restrict architectural variability and statistical robustness, which may limit the findings to this setting. Instead of representing typical courtyard reactions, observed EEG patterns like elevated Theta power and Alpha suppression might reflect the spatial and sensory characteristics of this environment.

The study supports the hypothesis that courtyard spatial configuration and visual stimuli like vegetation and spatial enclosure could affect cognitive and emotional states, and it does so while establishing a methodological framework for incorporating neurophysiological tools into architectural research. For future research on neurolandscapes in educational settings, this provides an evidence-based background. Though useful for field research, the use of a single-channel EEG device limits the depth of neurophysiological analysis by sacrificing spatial resolution and the capacity to identify activity across cortical regions. Furthermore, uncontrolled environmental factors may have introduced noise into the EEG data, even though efforts were made to minimize disturbances in a quieter, enclosed courtyard area. These factors include ambient noise, visual distractions from passersby, and fluctuating light conditions. Furthermore, generalizability may be further limited by the homogeneous sample of students from the same academic department who have comparable schedules, educational backgrounds, and stressors. To improve the findings' applicability, future studies should investigate a variety of spatial contexts, configurations, dimensions, height-to-width ratios, and enclosure levels.

7. Conclusions

An analysis of EEG data from 16 participants revealed a significant Theta increase (+3.27%, $p = 0.0041$), reflecting enhanced internal relaxation, psychological restoration, fatigue recovery, and a gateway to learning through withdrawal from the external stressors (4–8 Hz, associated with sleep and daydreaming), as well as a high Alpha decrease (−3.63%, $p = 0.0015$), indicating fascination and sensory engagement (8–12 Hz, typically linked to alertness, calmness, and mental coordination), which is influenced by the courtyard's spatial design. Individual differences (e.g., P3, P5 with more Theta, P1, P7 with less Alpha) suggest varying responses to courtyard shape, enclosure, and vegetation-to-hardscape ratio. Enclosed spaces with more vegetation possibly enhance Theta-based learning readiness and open spaces with more hardscape, possibly suppressing Alpha's calming effect through more external focuses. Psychologically, these findings position courtyards as learning settings that support restoration and cognitive readiness via Theta, while the Alpha decrease signifies a shift towards engagement, to the advantage of a balanced learning setting. Nevertheless, it demonstrated that despite its use as an indicator of relaxation and restoration, Alpha often functions as a suppressor in the analysis model. This is because it reflects the internal emotion in response to external stimuli, which could reflect individual preferences, rather than being used for rule generalization, as demonstrated in [63,64]. This reverberates on the direct relationship between higher Alpha power and familiarity of space, even if the space is not having a healing or relaxing effect. This would imply that Alpha reflects the internal emotions regarding space, and it begins internally rather than interpreting the impact of space on the interior emotions.

Finally, this study advocates for enclosed spaces with balanced proportions (approximate 1:1 height-to-width ratio). Moderate vegetation coverage (around 35%) was associated with increased Theta activity, suggesting improved relaxation and cognitive restoration. Seating arrangements that placed students near greenery and away from distractions further supported these effects. Natural sensory elements, such as subtle sounds from leaves or wind, also contributed to a calming atmosphere. Additionally, positioning students in

slightly unfamiliar parts of the courtyard appeared to stimulate gentle engagement and soft fascination. To enhance mental restoration in educational spaces, courtyard designs should prioritize enclosure, natural elements, varied planting, comfortable seating, and sensory richness—while avoiding overly open, noisy, or overly familiar layouts.

Future research should systematically investigate the neurophysiological responses to familiar versus unfamiliar spatial typologies to enhance the understanding of spatial familiarity as a cognitive and emotional variable. Employing a larger sample size would bolster statistical power and enable the exploration of optimal courtyard designs—such as enclosed versus open configurations with varying width-to-height proportions—to develop a regression model linking enclosure to restoration effects, thereby informing educational design optimization. To improve external validity, multi-site studies should be conducted, incorporating varied spatial configurations, vegetation densities, and enclosure levels. Additionally, including participants with diverse demographic and cognitive profiles (e.g., gender, age, neurodiversity, and differing environmental familiarity) would broaden the applicability of the findings.

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References

1. Reinilä, E.; Kekäläinen, T.; Saajanaho, M.; Kokko, K. The structure of mental well-being and its relationship with generativity in middle adulthood and the beginning of late adulthood. *Int. J. Behav. Dev.* **2023**, *47*, 328–338. [CrossRef]
2. Lin, E. Well-being. In *Routledge Encyclopedia of Philosophy*; Routledge: London, UK, 2022. [CrossRef]
3. Rhee, J.H.; Schermer, B.; Cha, S.H. Effects of indoor vegetation density on human well-being for a healthy built environment. *Dev. Built Environ.* **2023**, *14*, 100172. [CrossRef]
4. Baxter, L.; Burnell, K. What is wellbeing and how do we measure and evaluate it? In *Archaeology, Heritage, and Wellbeing*; Routledge: London, UK, 2022; pp. 7–25. [CrossRef]
5. Jarden, A.; Roache, A. What Is Wellbeing? *Int. J. Environ. Res. Public Health* **2023**, *20*, 5006. [CrossRef]
6. McCay, L.; Bremer, I.; Endale, T.; Jannati, M.; Yi, J. *Urban Design and Mental Health*; Springer: Singapore, 2017; pp. 1–24. [CrossRef]
7. Ulrich, R.S. View Through a Window May Influence Recovery from Surgery. *Science* **1984**, *224*, 420–421. [CrossRef]

8. Kaplan, S. The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psychol.* **1995**, *15*, 169–182. [CrossRef]
9. Closs, L.; Mahat, M.; Imms, W. Learning environments' influence on students' learning experience in an Australian Faculty of Business and Economics. *Learn. Environ. Res.* **2022**, *25*, 271–285. [CrossRef]
10. Foellmer, J.; Kistemann, T.; Anthonj, C. Academic Greenspace and Well-Being—Can Campus Landscape be Therapeutic? Evidence from a German University. *Wellbeing Space Soc.* **2021**, *2*, 100003. [CrossRef]
11. Ohly, H.; White, M.P.; Wheeler, B.W.; Bethel, A.; Ukoumunne, O.C.; Nikolaou, V.; Garside, R. Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *J. Toxicol. Environ. Health Part B* **2016**, *19*, 305–343. [CrossRef]
12. Valtchanov, D.; Ellard, C.G. Cognitive and affective responses to natural scenes: Effects of low-level visual properties on preference, cognitive load and eye-movements. *J. Environ. Psychol.* **2015**, *43*, 184–195. [CrossRef]
13. Salameh, M.; Touqan, B.; Suliman, A. Enhancing student satisfaction and academic performance through school courtyard design: A quantitative analysis. *Archit. Eng. Des. Manag.* **2024**, *20*, 911–927. [CrossRef]
14. Norman, J.F.; Carmichael, M.; Hagan, E.; Mishchuk, Y.; Bryant, E.N.; Ramirez, A.B.; Sutton, A. Visual outdoor space perception. *Sci. Rep.* **2025**, *15*, 11549. [CrossRef] [PubMed]
15. Zheng, H.; Luo, M.; Wang, Y.; Wei, Y. Multi-Sensory Interaction and Spatial Perception in Urban Microgreen Spaces: A Focus on Vision, Auditory, and Olfaction. *Sustainability* **2024**, *16*, 8809. [CrossRef]
16. Guo, W.; Wen, H.; Liu, X. Research on the psychologically restorative effects of campus common spaces from the perspective of health. *Front. Public Health* **2023**, *11*, 1131180. [CrossRef] [PubMed]
17. Ibrahim, I.; Al Badri, N.; Mushtaha, E.; Omar, O. Evaluating the Impacts of Courtyards on Educational Buildings, Case Study in the University of Sharjah. *Sustainability* **2021**, *14*, 141. [CrossRef]
18. Callaghan, A.; McCombe, G.; Harrold, A.; McMeel, C.; Mills, G.; Moore-Cherry, N.; Cullen, W. The impact of green spaces on mental health in urban settings: A scoping review. *J. Ment. Health* **2021**, *30*, 179–193. [CrossRef]
19. Olszewska, A.A.; Marques, P.F.; Barbosa, F. Enhancing Urban Landscape with Neuroscience Tools: Lessons from the Human Brain. *Citygreen* **2015**, *1*, 60. [CrossRef]
20. Olszewska-Guizzo, A.; Sia, A.; Fogel, A.; Ho, R. Features of urban green spaces associated with positive emotions, mindfulness and relaxation. *Sci. Rep.* **2022**, *12*, 20695. [CrossRef]
21. Jeon, J.Y.; Jo, H.I.; Lee, K. Psycho-physiological restoration with audio-visual interactions through virtual reality simulations of soundscape and landscape experiences in urban, waterfront, and green environments. *Sustain. Cities Soc.* **2023**, *99*, 104929. [CrossRef]
22. Wei, N.; Jiangxu, J.; Mimi, W.; Jin, S.; Gang, L. Research on the Impact of Panoramic Green View Index of Virtual Reality Environments on Individuals' Pleasure Level Based on EEG Experiment. *Landsc. Archit. Front.* **2022**, *10*, 36–51. [CrossRef]
23. Seiz, A.; Kweon, B.S.; Ellis, C.D.; Oh, H.; Pietro, K. Exploring the Psychophysiological Effects of Viewing Urban Nature through Virtual Reality Using Electroencephalography and Perceived Restorativeness Scale Measures. *Sustainability* **2023**, *15*, 13090. [CrossRef]
24. Aghabozorgi, K.; van der Jagt, A.; Bell, S.; Smith, H. The role of university campus landscape characteristics in students' mental health. *Urban For. Urban Green.* **2025**, *111*, 128863. [CrossRef]
25. Garg, A.M. Open Spaces in a Institutional Campus Leads to Active Environment. *Int. J. Sci. Res. Eng. Manag.* **2024**, *8*, 1–5. [CrossRef]
26. Stigsdotter, U.K.; Grahn, P. What Makes a Garden a Healing Garden? Available online: https://www.researchgate.net/publication/234072230 (accessed on 2 April 2025).
27. Si, B.; binti Mohd Noor, A.I.; Wen, K. Linking University Campus Green Space and Students' Mental Health and Well-Being: A Systematic Literature Review. *Int. J. Acad. Res. Environ. Geogr.* **2024**, *10*, 31–47. [CrossRef]
28. Olszewska-Guizzo, A.; Fogel, A.; Escoffier, N.; Sia, A.; Nakazawa, K.; Kumagai, A.; Dan, I.; Ho, R. Therapeutic Garden With Contemplative Features Induces Desirable Changes in Mood and Brain Activity in Depressed Adults. *Front. Psychiatry* **2022**, *13*, 757056. [CrossRef]
29. Krefis, A.; Augustin, M.; Schlünzen, K.; Oßenbrügge, J.; Augustin, J. How Does the Urban Environment Affect Health and Well-Being? A Systematic Review. *Urban Sci.* **2018**, *2*, 21. [CrossRef]
30. Choi, H.S.; Bruyns, G.; Zhang, W.; Cheng, T.; Sharma, S. Spatial Cognition and Three-Dimensional Vertical Urban Design Guidelines—Cognitive Measurement and Modelling for Human Centre Design. *Urban Sci.* **2023**, *7*, 125. [CrossRef]
31. Mariani Wigley, I.C.; Nazzari, S.; Pastore, M.; Provenzi, L.; Barello, S. The contribution of environmental sensitivity and connectedness to nature to mental health: Does nature view count? *J. Environ. Psychol.* **2025**, *102*, 102541. [CrossRef]
32. Roe, J.; Aspinall, P. The restorative outcomes of forest school and conventional school in young people with good and poor behaviour. *Urban For. Urban Green.* **2011**, *10*, 205–212. [CrossRef]
33. Gao, T.; Zhang, T.; Zhu, L.; Gao, Y.; Qiu, L. Exploring psychophysiological restoration and individual preference in the different environments based on virtual reality. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3102. [CrossRef]

34. Lau, S.S.Y.; Gou, Z.; Liu, Y. Healthy campus by open space design: Approaches and guidelines. *Front. Archit. Res.* **2014**, *3*, 452–467. [CrossRef]
35. Peker, E.; Ataöv, A. Exploring the ways in which campus open space design influences students' learning experiences. *Landsc. Res.* **2020**, *45*, 310–326. [CrossRef]
36. Ribeiro, H.; de S. Santana, K.V.; Oliver, S.L. Natural Environments in University Campuses and Students' Well-being. *arXiv* **2024**. [CrossRef]
37. Ellard, C. Neuroscience, Wellbeing, and Urban Design: Our Universal Attraction to Vitality. *Psychol. Res. Urban Soc.* **2020**, *3*, 6. [CrossRef]
38. Russo, A. Urban Green Spaces and Healthy Living: A Landscape Architecture Perspective. *Urban Sci.* **2024**, *8*, 213. [CrossRef]
39. Hughes, H.; Franz, J.; Willis, J. *School Spaces for Student Wellbeing and Learning Insights from Research and Practice*; Springer: Singapore, 2019.
40. Juba, İ.; Bogenç, Ç. Impact of Courtyard Architecture on Personal Well-Being and Human Health. *Türkiye Peyzaj Araştırmaları Derg.* **2024**, *7*, 204–212. [CrossRef]
41. Nie, X.; Wang, Y.; Zhang, C.; Zhao, Y.; Kirkwood, N. The varied restorative values of campus landscapes to students' well-being: Evidence from a Chinese University. *BMC Public Health* **2024**, *24*, 487. [CrossRef]
42. Wen, Q.; Zhou, Q.; Ye, H.; Guo, Q.; Shan, J.; Huang, Z. A Perceptual Assessment of the Physical Environment in Teaching Buildings and Its Influence on Students' Mental Well-Being. *Buildings* **2024**, *14*, 1790. [CrossRef]
43. Karimi, N.; Sajadzadeh, H.; Aram, F. Investigating the Association between Environmental Quality Characteristics and Mental Well-Being in Public Open Spaces. *Urban Sci.* **2022**, *6*, 20. [CrossRef]
44. Cao, Y.; Huang, L. Research on the Healing Effect Evaluation of Campus' Small-Scale Courtyard Based on the Method of Semantic Differential and the Perceived Restorative Scale. *Sustainability* **2023**, *15*, 8369. [CrossRef]
45. Alnusairat, S.; Al-Shatnawi, Z.; Ayyad, Y.; Alwaked, A.; Abuanzeh, N. Rethinking Outdoor Courtyard Spaces on University Campuses to Enhance Health and Wellbeing: The Anti-Virus Built Environment. *Sustainability* **2022**, *14*, 5602. [CrossRef]
46. Farid, M.; Mohamed, S.; Nasr, S.; Assistant, T. Keywords-Academic Open Spaces (AOS), Social Health, Physical Health, Mental Health. Available online: https://www.iol.co.za/ (accessed on 20 May 2025).
47. Faul, F.; Erdfelder, E.; Lang, A.-G.; Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* **2007**, *39*, 175–191. [CrossRef]
48. Chen, Z.; He, Y.; Yu, Y. Attention restoration during environmental exposure via alpha-theta oscillations and synchronization. *J. Environ. Psychol.* **2020**, *68*, 101406. [CrossRef]
49. Chang, S.; Jun, H. Hybrid deep-learning model to recognise emotional responses of users towards architectural design alternatives. *J. Asian Archit. Build. Eng.* **2019**, *18*, 381–391. [CrossRef]
50. Wu, J.; Zhong, Y.; Wang, Y.; Gong, C. Investigating the Relation between Visitor Attention and Visual Quality of Forest Landscape: A Mobile EEG Study. *Forests* **2022**, *13*, 1668. [CrossRef]
51. Zhang, Z.; Zhuo, K.; Wei, W.; Li, F.; Yin, J.; Xu, L. Emotional responses to the visual patterns of urban streets: Evidence from physiological and subjective indicators. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9677. [CrossRef]
52. Li, Z.; Kang, J. Sensitivity analysis of changes in human physiological indicators observed in soundscapes. *Landsc. Urban Plan.* **2019**, *190*, 103593. [CrossRef]
53. Song, R.; Chen, Q.; Zhang, Y.; Jia, Q.; He, H.; Gao, T.; Qiu, L. Psychophysiological restorative potential in cancer patients by virtual reality (VR)-based perception of natural environment. *Front. Psychol.* **2022**, *13*, 1003497. [CrossRef]
54. Ren, H.; Zheng, Z.; Zhang, J.; Wang, Q.; Wang, Y. Electroencephalography (EEG)-Based Comfort Evaluation of Free-Form and Regular-Form Landscapes in Virtual Reality. *Appl. Sci.* **2024**, *14*, 933. [CrossRef]
55. Guo, L.N.; Zhao, R.L.; Ren, A.H.; Niu, L.X.; Zhang, Y.L. Stress recovery of campus street trees as visual stimuli on graduate students in autumn. *Int. J. Environ. Res. Public Health* **2020**, *17*, 148. [CrossRef]
56. Nota, A.; Tecco, S.; Ehsani, S.; Padulo, J.; Baldini, A. Postural stability in subjects with temporomandibular disorders and healthy controls: A comparative assessment. *J. Electromyogr. Kinesiol.* **2017**, *37*, 21–24. [CrossRef]
57. Olszewska-Guizzo, A. *Neuroscience for Designing Green Spaces*; Routledge: New York, NY, USA, 2023. [CrossRef]
58. Stevenson, M.P.; Dewhurst, R.; Schilhab, T.; Bentsen, P. Cognitive Restoration in Children Following Exposure to Nature: Evidence From the Attention Network Task and Mobile Eye Tracking. *Front. Psychol.* **2019**, *10*, 42. [CrossRef] [PubMed]
59. Chang, C.-Y.; Hammitt, W.E.; Chen, P.-K.; Machnik, L.; Su, W.-C. Psychophysiological responses and restorative values of natural environments in Taiwan. *Landsc. Urban Plan* **2008**, *85*, 79–84. [CrossRef]
60. Ulrich, R.S. Natural Versus Urban Scenes. *Environ. Behav.* **1981**, *13*, 523–556. [CrossRef]
61. Grassini, S.; Revonsuo, A.; Castellotti, S.; Petrizzo, I.; Benedetti, V.; Koivisto, M. Processing of natural scenery is associated with lower attentional and cognitive load compared with urban ones. *J. Environ. Psychol.* **2019**, *62*, 1–11. [CrossRef]
62. Koivisto, M.; Jalava, E.; Kuusisto, L.; Railo, H.; Grassini, S. Top-Down Processing and Nature Connectedness Predict Psychological and Physiological Effects of Nature. *Environ. Behav.* **2022**, *54*, 917–945. [CrossRef]

63. Neale, C.; Aspinall, P.; Roe, J.; Tilley, S.; Mavros, P.; Cinderby, S.; Coyne, R.; Thin, N.; Ward Thompson, C. The impact of walking in different urban environments on brain activity in older people. *Cities Health* **2020**, *4*, 94–106. [CrossRef]
64. Brielmann, A.A.; Buras, N.H.; Salingaros, N.A.; Taylor, R.P. What Happens in Your Brain When You Walk Down the Street? Implications of Architectural Proportions, Biophilia, and Fractal Geometry for Urban Science. *Urban Sci.* **2022**, *6*, 3. [CrossRef]

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