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A SYSTEMATIC REVIEW OF ELECTROENCEPHALOGRAPHIC METHODOLOGIES, TECHNOLOGIES, AND CONSEQUENCES IN NEURO-LANDSCAPE PROSPECT ON PSYCHOLOGICAL RESTORATION FOR UNIVERSITY STUDENTS.

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ABSTRACT

Nowadays, university students are more likely to suffer from depression, stress, and anxiety, among others, which have a terrible impact on their quality of life. Additionally, there is a low level of help-seeking due to a lack of awareness and an adverse mindset towards the value of mental health. However, there are also options for them to explore the usefulness of a restorative setting that has been scientifically proven to help heal emotions. Similarly, the psychological restorative effects of urban natural landscape exposure are associated with human brain stimulation patterns and emotional capacity. As a result, the convergence of neuroscience and landscape architecture known as neuro-landscape will produce considerable potential for psychological restoration underutilisation. This study investigates electroencephalographic (EEG) testimony to comprehend the methodologies, technologies, and consequences until it develops a neuro-landscape prospect. PRISMA, a systematic literature review tool, reviewed 25 papers. Deeply understanding the setting, approach, stimuli, device, electrode, and outcome of the EEG experiment will assist the researcher in addressing Malaysian university students with mental health difficulties. This study also discovered that incorporating landscape design and neuroscience into conventional restorative environmental analysis methodologies for psychological restoration can provide more conclusive evidence.

1. INTRODUCTION

Rapid urbanisation improves socioeconomic, educational, and employment opportunities, but it also contributes to mental health problems. It has altered the physical environment of the urban setting, putting the urban community's social well-being at risk (Teng et al., 2018). Eventually, mental health problems will be most prevalent in the urban community, including among university students. They are the group that struggles with academic stress during the arduous stage of the youth-to-adulthood transition (Omar et al., 2020). They have a mindset in which job prospects require strong credentials based on Cumulative Grade Point Average (CGPA) because competition is fierce these days. Therefore, they are extremely vulnerable to anxiety, stress, and depression, all of which have a detrimental effect on their quality of life. For instance, this problem primarily impacts Malay university students, with 33 per cent of them experiencing stress and 11 per cent reporting depression (Gan & Hue, 2019). When COVID-19 began spreading globally, the problem got even worse. The most severe anxiety was reported by 2.8 per cent of the 983 university students in Malaysia who had been screened for the empirical study at the time (Sundarasen et al., 2020). The problem is made harder by the fact that students have negative stereotypes about mental health issues and are discouraged from getting help (Kotera et al., 2020). Therefore, a preventative measure is required to assist them in overcoming this problem. Significant empirical evidence suggests that exposure to natural environments can benefit sufferers

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The natural environment has a significant effect on mental health improvement. Empirical research has revealed that it possesses certain characteristics and plays a substantial role in psychological restoration (Shaffee et al., 2018). For example, even a green alley in the neighbourhood can alleviate mental fatigue. A study done by Weber & Schneider (2021) using in-depth interviews with 22 residents revealed that they had a restorative experience (fascination, compatibility, and extent) on the green alley. Besides, residents' attention was drawn to the aesthetic elements, which increased calm reflection. It demonstrates that restorative experiences can be found in various settings, including invented landscapes like the green alley. An urban park is another type of green urban space that affects mental health, yet significant evidence of urban parks and mental health is still in its infancy (Deng et al., 2020). It is time to investigate the impact of urban parks on students suffering from psychological distress. A necessitates the adoption of appropriate research methodologies. Previously, self-assessment for measuring psychological restoration was not fully capable of accurately reflecting underlying brain activity (Sacchelli et al., 2020). This study looks at electroencephalographic (EEG) evidence in understanding the methodologies, technologies, and consequences until it generates a neuro-landscape prospect via a systematic literature review.

2. LITERATURE REVIEW

2.1 Neuro-landscape and Restorative Environment

The emergence of neuroscience and landscape architecture promises to provide an empirical platform for studying the psychological impact of urban nature. Psychological restoration entails both cognitive and emotional brain activities involving neural potential. The neural potential is the electrical transmission of information into cell membranes due to various stimuli, activities, and exposures (Olszewska et al., 2015). It was derived from the individual's visual assessment of things that affect perception, captured by the brain's low-level to high-level processing areas. For instance, the parahippocampal cortex is a high-level processing area that is particularly sensitive to environmental cues, along with the occipital (perceptive attribute processing) and retrosplenial cortex (envisioned spatial processing) (Coburn et al., 2017). Besides, visual information drives affective reactions to environmental stimuli via automatic and unconscious processing in the limbic system (Ulrich, 1983). It proves the significance of environmental stimuli in influencing human brain activity. However, it is difficult to assess an individual's actual perceptual and affective responses to environmental stimuli.

A neuro-landscape concept will aid in understanding human brain activity in both perceptive and affective responses. Although integrating neuroscience and architecture in relation to brain activity is not a novel idea (Coburn et al., 2017; Sacchelli et al., 2020), empirical evidence in landscape architecture is still limited. Self-assessment was previously dominant in determining the perceptual impact of environmental stimuli (Berto, 2005; Malekinezhad et al., 2020; Martinez-Soto, 2014). In contrast, the effective measure made use of advanced technologies such as Magnetic Resonance Imaging (MRI) (Tang et al., 2017), Near-Infrared Spectroscopy (NIRS) (Hoffmann et al., 2019), and electroencephalography (EEG) (Olszewska-Guizzo et al., 2018). The advancement of technologies for measuring brain activities in neuroscience, which can be integrated by landscape architecture as is common in environmental design, will yield significant evidence in this study. Also, combining the two methods can overcome the limitation. As a first step, it is necessary to identify the natural environment that has a restorative effect (environmental stimuli).

The natural or invented landscape is brimming with restorative qualities that profoundly impact psychological restoration. Stress-Reduction Theory (Ulrich et al., 1991) and Attention-Restoration Theory (Kaplan, 1995) are two credible ideas that have revealed scientific evidence on psychological restoration influenced by the restorative environment. Each restorative environment will serve as a therapy garden for people in various designs, configurations, and programmes (Stigsdotter, 2015), especially for stress reduction (Shaffee et al., 2018). For instance, a Contemplative Landscape Model (CLM) was created to assess the restorative environment by stressing seven characteristics. The seven characteristics are landscape layers, landform, vegetation, colour and light, compatibility, archetypal elements, and the character of peace and silence (Agnieszka et al., 2018). Recent studies have progressively included this notion in analysing the contemplativeness of urban parks that promote mental health improvement, notably in Malaysia (Mohd Salleh et al., 2021; Mohd Salleh, Othman, Abd Malek, & Suddin, 2021) and Singapore (Olszewska-Guizzo et al., 2018; Yanru et al., 2020). Although several metrics are available, not all are reliable and valid for specific circumstances. In this regard, CLM is deemed reliable and valid for future research based on the studies mentioned above.

3. METHODS

In this study, the Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) was used to identify the prospect of neuro-landscape on psychological restoration. This systematic procedure aids researchers in obtaining significant evidence to support the study's argument. First, the evidence was gathered using Google Scholar, Web of Science, and Scopus databases. Next, the researcher defines evidence criteria based on years published between 2011 and 2021. In addition, keywords such as "Psychological Restoration," "Electroencephalographic," and "students" were used to retrieve the evidence. Finally, the evidence of articles that match the aforementioned criteria will be filtered using the PRISMA technique, which involves screening, eligibility, and inclusion, as illustrated in Figure 1.

4. RESULT AND DISCUSSION

Figure 1 shows that a total of 25 published articles matched the inclusion criteria for this systematic literature review. Then the articles were abstracted based on specific themes such as sources, country, type of stimuli, approach applied, tool and equipment, number of channels (electrodes), and outcome, as displayed in Table 1. This section will go through each of these themes in depth.

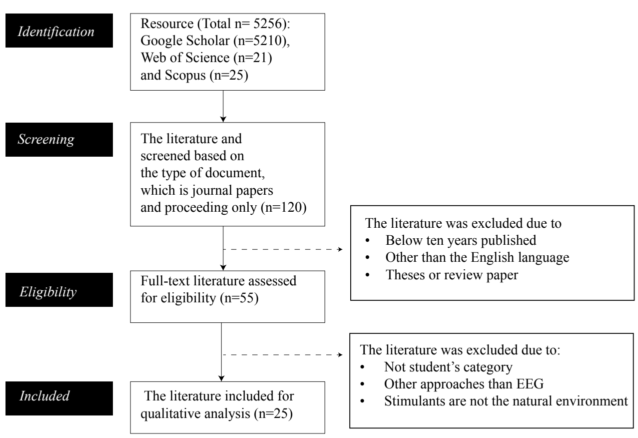

***Figure 1**: The Flow Diagram of PRISMA (Source: Moher et al., 2009)*

***Table 1**: The Psychological Restoration Studies via Electroencephalographic EEG*

Sources	Setting	Stimuli	Approach	Device	Electrodes	Psychological Outcome
Chiang & Weng (2021)	Forest	Video	Virtual	NeuroSky US	1 Channel	Physiological restoration
Yuting et al. (2021)	Grassland, forest, water	Video	Virtual	lamp	32 Channels	Relaxation
Li et al. (2021)	lawn, garden, water feature, forest	Video	Virtual	BIOPAC	2 Channels	Physiological restoration
Jo, Park, & Yeon (2021)	Forest	Video	Virtual	BIOS-ST	8 Channels	Attention
Zeng et al. (2021)	Greenspace	Video	Virtual	Emotiv EPOC	14 Channels	Emotional expression
Chen, He, & Yu, (2020)	Wooded garden, trafficked road	In-situ	Actual	Emotiv EPOC	14 Channels	Physiological restoration
Lin et al. (2020)	Small green space	In-situ	Actual	Emotiv EPOC	14 Channels	Relaxation
Hassan et al. (2020)	Indoor plant	In-situ	Actual	NeuroSky CHINA	1 Channel	Stress reduction
Wang et al. (2020)	Bamboo forests	Image	Virtual	Neuro Harmony	3 Channels	Relaxation
Tao et al. (2020)	Indoor plant	In-situ	Actual	NeuroSky CHINA	1 Channel	Relaxation
Zaino & Abbas (2020)	Beach, Pond	In-situ	Actual	EMOTIV Insight	5 Channels	Emotional expression
Olszewska-Guizzo et al. (2020)	Neighbourhood green space	In-situ	Actual	Brain Analyser 2	16 Channels	Positive mood
Guo et al. (2020)	Street trees	Image	virtual	NeuroSky CHINA	1 Channel	Stress recovery
Ayman & Yusoff (2020)	Beach/Pond	In-situ	Actual	EMOTIV Insight	5 Channels	Emotional expression
Oh, Kim, & Park (2019)	Indoor plants	In-situ	Actual	Quick-20	8 Channels	Attention
Cheon et al. (2019)	Virginia Tech's campus	Image	Virtual	Emotiv EPOC	14 Channels	Restorative recovery
Gao et al. (2019)	Open green space	Image	Virtual	NeuroSky CHINA	2 Channels	Physiological restoration
Su et al. (2019)	Green spaces	Video	Virtual	NeuroScan	30 Channels	Physiological restoration
Jiang et al. (2019)	Garden, natural landscape	Image	Virtual	NeuroSky CHINA	1 Channel	Psychophysi-ological
Kim, Cheon, & Kang (2019)	Campus spaces	Image	Virtual	Emotiv EPOC	8 Channels	Physiological restoration
Chung, Lee, & Park (2018)	Seaside, grassland, hilly scenes.	Image	Virtual	PST's E-Prime Extensions	64 Channel	Physiological restoration
Duan, Yakovleva, & Norcia (2018)	Outdoor environment	Image	Virtual	HydroCell Geodesic Sensor Nets and	128 Channels	Physiological restoration
Olszewska et al. (2018)	Urban parks	Video	Virtual	Eno	8 Channels	Relaxation
Chen, He, & Yu, (2016)	Wooded garden, trafficked road	In-situ	Actual	Emotiv EPOC	14 Channels	Physiological restoration
Roe et al. (2013)	Fields, forests, parkland	Image	Virtual	Emotiv EPOC	12 Channels	Relaxation

4.1 Setting and Context of Electroencephalographic EEG Studies

In an urban context, two distinct landscapes affect psychology differently: the natural landscape and the invented landscape (Othman et al., 2020), which may offer healing properties. According to recent studies, the natural landscape category was used by 24 per cent of the reviewed articles for their setting on psychological restorative impact studies via Electroencephalographic (EEG). About 60 per cent is dominated by invented landscapes such as urban green spaces (Zeng et al., 2021; Lin et al., 2020; Chen, He, & Yu, 2020; Gao et al., 2019; Olszewska et al., 2018; Duan, Yakovleva, & Norcia, 2018; Chen, He, & Yu, 2016), neighbourhood green spaces (Olszewska-Guizzo et al., 2020), campus environment (Cheon et al., 2019; Kim, Cheon, & Kang, 2019), street planting (Guo et al., 2020), and indoor plants (Hassan et al., 2020; Tao et al., 2020; Oh, Kim, & Park, 2019). In the remaining 16 per cent of studies, researchers compared the psychological influence of natural and invented landscapes (Li et al., 2021; Zaino & Abbas, 2020; Ayman & Yusoff, 2020; Jiang et al., 2019).

The results of psychological restoration are frequently comparable, despite differences in context and setting. These studies showed that, as long as the landscape has a restorative capacity, an individual's psychological health can benefit from being in either a natural or invented landscape. It was also abundantly evident that the individual prefers to relax and release their distress in both landscapes. Evidently, high alpha brain responses in EEG are clearly associated with beneficial psychological restoration. For instance, the forest can offer relaxation (Yuting et al., 2021) and concentration (Jo, Park, & Yeon, 2021), while green spaces encourage a positive mood (Olszewska-Guizzo et al., 2020) and stress relief (Guo et al., 2020). Not only the types of settings that deserve attention but also other factors like the weather, noise, and smell greatly impact the EEG outcomes. It should be highlighted that unpredictable weather (such as a tropical climate) will impede psychological restoration even in settings with restorative power. For example, high contemplative landscapes can induce frontal alpha asymmetry (FAA), but unregulated temperature and humidity have harmed research outcomes (Olszewska-Guizzo et al., 2020). Once the temperature and humidity factors were under control, the results showed a sizable influence. Thus, setting and context selection must be appropriately considered when analysing psychological restoration using EEG since brain responses are sensitive to the type of driver or stimuli applied.

4.2 Electroencephalographic EEG Approach and Stimuli

Notably, 16 studies were conducted virtually using an electroencephalogram, whereas nine studies were conducted physically. The 16 experimental studies are carried out in a laboratory setting with additional digital instruments and equipment in a dedicated room, while the other nine studies are carried out on-site. When it comes to quantifying psychological restoration, both approaches offer considerable advantages and disadvantages. For instance, the capacity to constantly control light intensity, humidity, and temperature is an advantage of a laboratory setting approach (Lin et al., 2020; Hassan et al., 2020). It is crucial to regulate since these parameters can influence the trial outcome in relation to on-site disadvantages for an actual experimental study (Wu et al., 2021; Olszewska-Guizzo et al., 2020). In addition, the presence of a human figure also affects brain activity (Kim, Cheon, & Kang, 2019). The absence of a human figure in a natural setting has the greatest chance of replenishing attentional capacity and mental fatigue (Wang et al., 2016)but few have measured restorativeness of specific landscape components, especially in Chinese settings. Because the rapid urbanization of China is accompanied by increasing predomination of hardscape components in cities, the restorative quality of urban green space is a crucial issue. This study explored the stress recovery effects of different videotaped scenes, using six urban parks and one urban roadway scene. Potentially restorative urban park scenes were controlled for nature-based vs. hardscape components, presence/absence of people, and level of openness. Methods: Subjects were Chinese university students (N = 140. In this regard, these parameters must be reinforced in both approaches if relevant results are to be obtained. The stimuli to be used in the experiment should also be deliberately selected. According to this review, the virtual experiments used two types of stimuli: video (seven studies) and image (nine studies). Both stimuli consistently have a major impact on psychological recovery, despite their difference.

For instance, previous studies displayed their stimuli in a three-dimensional interactive virtual reality scene known as Virtual Reality (VR) (Li et al., 2021; Jo, Park, & Yeon, 2021; Guo et al., 2020). That experiment promises advantages since it replicates the real environment, even though it is a computer simulation. Also, hearing natural acoustic sounds can help people relieve tension faster, which can be conveyed through video stimuli (Zeng et al., 2021). Image stimuli have a comparable impact on psychological restoration as well. A key point is that the images must depict a nature-based scene, whether it be a forest (Wang et al., 2020; Roe et al., 2013), an urban park (Lin et al., 2020; Gao et al., 2019; Olszewska et al., 2018), street vegetation (Guo et al., 2020), or parkland (Chung, Lee, & Park, 2018; Roe et al., 2013). A specific location and actual scene are prominent as stimuli for the on-site experiment. According to this review, these stimuli were differently employed in nine studies. All of these stimuli, from a single element, such as indoor vegetation (Hassan et al., 2020; Oh, Kim, & Park, 2019), to a small green space (Lin et al., 2020), to a neighbourhood and an urban park (Olszewska et al., 2018), play a significant role in psychological restoration. In order to quantify the restorative experience, dedicated technology is required.

4.3 The Practical Device of Electroencephalographic EEG

The reviewed studies made use of a variety of devices for their Electroencephalographic (EEG) studies. The previous studies used 13 distinct types of EEG devices available from various companies. The most widely utilised device in the reviewed studies is from the United States of America (LiveAmp, BIOPAC, Emotiv EPOC, Emotiv INSIGHT, Neuro Harmony, Quick-20, NeuroScan, PST's E-Prime Extensions for Net Station (EENS), HydroCell Geodesic Sensor Nets, Enobio), followed by China (NeuroSky), South Korea (BIOS-ST), and Germany (Brain Analyzer 2). In this regard, the Emotiv EPOC is the most prominent device among researchers (Zeng et al., 2021; Chen, He, & Yu, 2020; Lin et al., 2020; Cheon et al., 2019; Kim, Cheon, & Kang, 2019; Chen, He, & Yu, 2016;

Roe et al., 2013). A device called NeuroSky is another example of a user device, especially in China (Hassan et al., 2020; Tao et al., 2020; Guo et al., 2020; Gao et al., 2019; Jiang et al., 2019) as well as the USA (Chiang & Weng, 2021). Also, two studies used the Emotiv INSIGHT device for their respective experiments (Zaino & Abbas, 2020; Ayman & Yusoff, 2020).

It demonstrates that the availability of EEG devices is advancing globally. All of the devices had unique features, functions, and efficacy to quantify the psychological outcome by utilising a number of electrodes, brain wave patterns, and other measures. In essence, each of the tools displayed has advantages of its own; thus, determining which is superior is irrelevant in this study. Besides, it will prejudice one party and undermine trust if the comparisons presented are not equitable. This study determined that several regions, including America, Europe, and Asia, are accountable for this technological advancement. Indirectly, access to such technologies can make each region more easily accessible. The use of the device depends upon the purpose of the particular study, which will define the required number of electrodes. Each tool has a distinct number of electrodes available, ranging from the smallest (1 electrode) to the largest (128 electrodes), as shown in Table 1. Each electrode is responsible for measuring a different brain region, such as the frontal, temporal, central, parietal, and occipital lobes.

4.4 Psychological Measures and Outcomes

The psychological outcomes are determined by electrode placement, brain wave configuration, and other self-reported measures. The number of electrodes is proportional to the type of device manufactured. However, it can be adjusted to meet the objective of the individual study. For example, the Emotiv EPOC was originally designed with 14 electrodes or sensors, yet it can be utilised with only eight electrodes (Kim, Cheon, & Kang, 2019), twelve electrodes (Roe et al., 2013), or 14 electrodes (Zeng et al., 2021; Chen, He, & Yu, 2020; Lin et al., 2020; Cheon et al., 2019; Chen, He, & Yu, 2016). The most electrodes utilised in a single experiment were 128 (Duan, Yakovleva, & Norcia, 2018), whereas the lowest number was a single electrode (Chiang & Weng, 2021; Hassan et al., 2020; Tao et al., 2020; Guo et al., 2020; Jiang et al., 2019; Chung, Lee, & Park, 2018). There is no definite role or regulation to demonstrate efficacy and superiority based on the number of electrodes used. However, it is defined by the study's purpose, objective, and goal of measuring psychological implications using EEG. It also relates to the configuration of the human brain to position the electrodes. Each section of the human brain has its own wave that emphasises distinct psychological responses.

For instance, there are five types of brain waves: delta (< 4 Hz), theta (4–7 Hz), alpha (8–15 Hz), beta (16–31 Hz), and gamma (> 31 Hz) (Wojcik et al., 2018)especially for the patients with panic disorders, depression (including the depressive phase of bipolar disorder. Each wave reflects a psychological reaction such as awareness (gamma), attentiveness (beta), relaxation (alpha), fatigue (theta), and sleep (delta) (Zaino & Abbas, 2020)"A single word has the power to influence the expression of genes that regulate physical and emotional stress". However, could architectural space also speaks? Or alter the expression of genes? This study aimed to investigate the relationship between architecture, brain and genes. The objectives were to test the influence of architecture over brain's electrical-activity, and subsequently develop, a theory of space and genes. The research methodology involved three phases. Firstly, an integrated approach for literature review. Secondly, an experimental approach. Finally, an integrative analysis. Findings showed a significant change of brain-electricity by change of environments. Thus, alteration in the expression of genes.Keywords: Architecture; Emotions; Behaviour; Genes.eISSN: 2514-751X © 2020 The Authors. Published for AMER ABRA cE-Bs by e-International Publishing House, Ltd., UK. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/. Furthermore, the positioning of the electrodes must correspond to the psychological responses in a specific brain region, including the prefrontal lobe (Fp1 and Fp2), frontal lobe (F3, F4, F7, F8), temporal lobe (T3, T4, T5, T6), central lobe (C3, C4), and occipital lobe (C1, C2) (Rahman et al., 2021). This study found that the most frequently studied waves are alpha and beta. For example, Guo et al. (2020) discovered that when observing street planting, there were substantial variations between high alpha and low beta among 150 students. Besides, 32 students from the University of Porto revealed a neural activity pattern with high power beta and low power alpha while viewing contemplative landscape images (Olszewska et al., 2018). The remaining studies examine all types of brainwaves, including gamma (Jiang et al., 2019; Chen, He, & Yu, 2016) and theta (Jo, Park, & Yeon, 2021; Chen, He, & Yu, 2020; Oh, Kim, & Park, 2019). Not to mention that there are studies that use the self-reporting method to evaluate the restorative experience.

There are several post-test questionnaires for evaluating the restorative experience, such as the State-Trait Anxiety Inventory (STAI) (Jiang et al., 2019), Perceived Restorative Scale (PRS) (Chung, Lee, & Park, 2018), PRS and Recovery Scale (RS) (Cheon et al., 2019; Roe et al., 2013), Positive and Negative Affect Scale (PANAS) (Li et al., 2021), and Restoration Outcomes Scale (ROS) (Wang et al., 2020). These questionnaires are intended to validate the restorative experience in both directions (perceptive and affective). In other cases, the perceptual responses of respondents do not appear to coincide with their true feelings. For example, a high-anxiety individual will intend to focus on negative information retained in their mind for a lengthy moment, resulting in an attentional bias outcome (Li et al., 2021). Therefore, appropriate questions must be carefully chosen to resolve this concern. For instance, Cheon et al. (2019) employed two PRS questions and two RS questions in their study. Even though the original questions are distinct, they remain relevant to the goal of their study. However, the remaining studies continue using the original questionnaires developed by the former authors (Li et al., 2021; Wang et al., 2020; Jiang et al., 2019). Both approaches are appropriate because there is no obligation to adopt one over the other. According to this review, some studies did not use the self-reporting approach.

5. CONCLUSION

Based on the EEG testimonials, this systematic review reveals the prospect of a neuro-landscape towards psychological restoration among university students. The restorative environment is consistently vital in promoting mental health, particularly when combined with neuroscience (EEG evidence). The review also highlighted the important indications in evaluating psychological restoration, such as setting, approaches, stimuli, devices, electrodes, and outcomes. Future research can expand on prior studies by replicating them with more rigorous research designs to strengthen the empirical foundation. Furthermore, conventional restorative environmental analysis approaches for mental rehabilitation can be enhanced by integrating landscape design and neuroscience to offer more conclusive evidence. Unfortunately, there is a shortage of EEG evidence on restorative environments and psychological restoration in Malaysia, especially among Malaysian university students. This review provides a stepping stone for the researcher to attempt to address this challenge. However, several constraints must be addressed immediately in this review. First, the majority of studies are conducted outside the ASEAN region, which does not reflect Malaysia's tropical setting and climate. Only two studies were undertaken in Malaysia, including one in Singapore. However, the data is still in its infancy. Second, only single-language articles in English were selected for this review, resulting in a deficiency of substantial evidence in other languages. Third, the study period was limited to the first ten years (2011–2021), thereby relegating the previous study to the fringe (the last 15 years). The topic was probably widely debated 15 years ago, but it was not included in this review. In conclusion, the highlighted information would assist the researcher in addressing Malaysian university students with mental health concerns by utilising appropriate methodologies, technologies, and efficacy until it forms a neuro-landscape prospect.

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