Al-Qadisiyah Journal for Engineering Sciences 16 (2023) 180–186

Contents lists available at http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: https://qjes.qu.edu.iq

Promoting students' well-being indicators through adapting biophilic design attributes in Salahaddin University dormitories

Ardalan Baiz Hasa **and** ***Husein Ali Husein****

Department of Architectural Engineering, College of Engineering, University of Salahaddin, Erbil, Iraq.

ARTICLE INFO

Article history:
Received 22 February 2023
Received in revised form 05 April 2023
Accepted 20 August 2023

Keywords:
Biophilic design attributes
Well-being
University dormitories
virtual reality
stress
physical indicators

ABSTRACT

Due to its positive impact on human psychophysiological indicators, biophilic design can be implemented in various built environments. This design approach can be used when the connection to natural elements is limited and when the occupants feel stressed and uncomfortable in a specific space. Purposes: This research aims to investigate promoting Students' well-being indicators through adapting biophilic design attributes in Salahaddin University dormitories Subjects: a cross-sectional field experiment conducted with 39 University students. Design: The participants experienced one of the two simulated rooms by using a virtual reality headset (VR). The first was a biophilic design room BDR based on the adopted BDAs, and the second was a non-biophilic design room NBDR. Besides, all participants performed a stress induction task SIT. Measures: Participants' physiological indicators were measured twice, one before and the other after the experiment. Measures included heart rate HR, Systolic blood pressure SBP, and diastolic blood pressure DBP. Result: Paired-sample T-test was used to compare the mean of physiological indicators. The P-values of physiological indicators were statistically significant ($P<0.05$). Conclusion: This study provided statistical evidence that BDAs can provide a restorative environment that positively affects human psychophysiology indicators, and NBDR provides a more stressful environment. VR is a powerful research tool if an empirical experiment and time/cost limit are allowed.

1. Introduction

Students at universities frequently experience study-related stress as a result of high expectations from themselves and others, exam and class pressures, and a lack of time, skills, money, and sleep [1]. "These and related stressors can have a negative impact on student's health, well-being, and academic achievement" [2], [3].

If students experience such negative feelings during their lectures, they may persist during the day and influence their overall well-being [4]. In addition, according to the study [5] study-related stressors can negatively impact student academic achievement.

These negative impacts on students' well-being can be eliminated by facilitating Indoors, where the students spend time in there. Indoor nature in classrooms can positively reduce these related stresses and improve students' psychophysiological aspects [4]. The physical environment of educational building classrooms is a supportive environment that boosts students' performance [6], [7]. According to the studies [4], [8], [9], the presence of natural elements in the indoor environment of educational buildings is positively related to the student's attention and efficiency.

* *Corresponding author.*
E-mail address: husein.ali@su.edu.krd (Husein Ali Husein)

https://doi.org/10.30772/qjes. 2023.179985
2411-7773/

"Indoor nature can provide a range of positive physical and psychological health benefits" [10].

In addition, other strategies can be adopted to maximize well-being and physical indicators. Exposure to daylight significantly impacts users' physical and mental health [11]. The existence of water in a built environment gives a sense of calm, relaxation, and comfort [12], [13]. Using natural materials can reduce stress [13], have health benefits [14], and can help recover from stress and anxiety [15]. Using natural colors impacts students' emotions, including feelings of happiness and excitement [16]. According to [13], spatial features and characteristics of space have advanced human health and well-being. All the mentioned strategies fall into attributes of BD This study focuses on facilitating and adopting BDAs to promote and enhance student physical indicators and well-being.

1.1. Theory and application of biophilia

Biophilia as a theory was started when first mentioned by social-psychoanalyst Erich Fromm in 1964. Then the term biophilia became more popular when the Socio-biologist Edward O. Wilson described it in his work Biophilia (1984). but Biophilia theory did not receive broad perception and recognition even after two decades after it was first proposed. According to [17], the theory of biophilia is still in its initial development phase.

Biophilic design is the application of this theory. The first attempt to empirically apply this theory in a physical environment was by [18]. Stephen Kellert identified various mechanisms for creating a biophilic experience in buildings. [19] defined Biophilic design as an "extension of biophilia", and they stated it is an innovative way of design that tends to enhance human beings' connection with nature in workplaces to induce well-being effects.

The term "biophilia" comes from the Greek language and consists of two elements "Bio" and "Phile." The word "bio" denotes "life," and the suffix "phile" indicates "Who" loves. The notion of biophilia was initially presented by Erich Fromm, an American social psychotherapist, in his book The Heart of Man (1964) and described as "the passionate love of life and of all that is alive" [20]. When sociobiologist Edward O. Wilson published his book Biophilia (1984), the word "biophilia" became increasingly prominent, and he described biophilia as "the innate tendency to focus on life and lifelike processes" [21].

1.2. Impacts and benefits of Biophilic design in the built environments

Biophilic design is not specified to a particular building typology or a specific level of the built environment. Applications of biophilic design range in scale from interior design to building design to parks, streetscapes, and urban design [22].

Biophilic design is more complex than simply incorporating vegetation and greenery into buildings. It broadens the range by including various types of nature, such as physical, sensory, metaphorical, morphological, material, and spiritual (Zhong et al., 2021). As the Biophilic design enhances the incorporation of natural elements into different levels of the built environments, it has various significant impacts on human beings [22].

A successful biophilic-based designed building depends on to what extent the built environment is restorative. According to [11], A high-quality biophilic design significantly reduces stress within built environments and improves the users' physical health. Moreover, Biophilic design creates environments that are restorative to human psychology, relax the nervous system, and demonstrate the aesthetic of life [23]. Biophilic buildings must improve human well-being and comfort by providing a restorative environment for recovery from stress and mental fatigue. [24].

Biophilic architecture employs a design strategy that focuses on re-establishing the connection between people and nature [13]. Buildings should be designed in such a way that they increase the connection between occupants and nature [25]. The biophilic design creates an environment that improves the connection between humans and nature [26]. Biophilic design aims to positively affect occupants by connecting and linking them to nature [27].

1.3. University students and dormitory buildings

University Students often experience study-related stressors because of high achievement expectations, exams, study fees, economic conditions, and lack of time [1]. These study-related stressors can have a negative impact on students' academic achievement [2], [5]. Exposure to stressors can negatively impact individuals' health (Jex & Beehr, 1991) as cited in [1]. Direct contact with nature in classrooms can significantly promote attention and reduce related stresses [4]. During their classroom stay, university students must focus, absorb information, and pay more attention [4].

Among university students, special consideration should be taken to the students in dormitory buildings; besides other study-related stressors, leaving family is another stress on them. Family stressors were mentioned for several reasons, including leaving family behind to go to school [1]. In addition, most of the studies were conducted in the university buildings, neglecting the built environment in which the students spent roughly two-thirds of their time during the study season. The current study will be conducted in that specific area (The students' room).

1.4. Attributes and variables of Biophilic design.

Patterns and attributes are the terms and names that the researchers have used to determine the variable of this design approach. The most well-known studies are the study by [13], [18], [28].

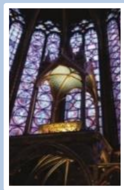
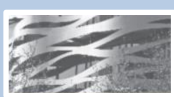
The researcher [18] recognized six biophilic design elements and roughly 70 attributes. The study of [28] Identified three main categories, which are: "nature in the space", "Natural analog", and "nature of the space". Furthermore, After seven years, [13]refined 70 design attributes and condensed them into twenty-four design attributes.

2. Literature review

Due to its significant impact on various psychophysiological indicators, many researchers investigated BD's impact. The effects vary and depend on the type of population and building.

According to the studies of [30], [31], [32], [33], BD positively impacts office workers. The researchers conducted their research in office buildings. They involved building officers in their study and adopted various BDAs. Research designs were simulated experiments, on-site experiments, and both together. The impacts were identified by measuring and monitoring the psychophysiological indicators of the participants. Their research showed that BDAs significantly promote physical well-being and effectively improve workplace health, well-being, productivity, work efficiency, and stress levels.

Table 1. Attributes and patterns of Biophilic design [29].

Attributes of Biophilic Design. Source: [13]		
Direct Experience of Nature	**Indirect Experience of Nature**	**Experience of Space and Place**
		
Light Air Water Plants Animals Weather Natural landscapes- - and ecosystems Fire	Images of nature Natural materials Natural colors Simulating natural light and air Naturalistic shapes and forms Evoking nature Information richness Age, change, and the patina- -of time Natural geometries Biomimicry	Prospect and refuge Organized complexity Integration of parts- - to wholes Transitional spaces Mobility and wayfinding Cultural and ecological- - Attachment to place
Patterns of Biophilic Design. Source: [28].		
Nature in the space	**Natural analogues**	**Nature of the space**
		
visual connection – -with nature non-visual connection- -with nature non-Rhythmic- -Sensory Stimuli Thermal &Airflow- - variability Presence of Water Dynamic & Diffuse Light Connection with- - Natural Systems	Biomorphic Forms & Patterns material Connection with nature Complexity & Order	Prospect Refuge mystery Risk/Peril

Moreover, other studies aimed to examine the impact of BD on students' stress, emotion, attention, health, and well-being. Longitudinal and cross-sectional experiments (empirical and simulated) were conducted in educational buildings at different levels (University, Secondary school, and secondary vocational school). The participants were college students, secondary students, and Vocational students. Students' well-being was measured using bio-sensors and medical tools; psychological indicators were measured through an adapting questionnaire. The researchers demonstrated many positive impacts of BD. The nature-based indoor environment might enhance stress recovery [34]. Indoor elements of visual biophilic design significantly impacted student emotions [16]. Biophilic design elements can enhance recovery from stress and reduce anxiety [15]. Classrooms with plants significantly impact students' performance [9]. Natural sound enhances and facilitates recovery from stress after a stressor task [35].

Nonetheless, the study of [11] investigated the impact of daylight on the healing environment in hospital rooms. The research was conducted in a hospital building, and the researchers adopted a questionnaire to get patients' self-reports. The researchers demonstrated a significant relationship between natural daylight and the healing process of the patients.

The research results clarify that BDAs are a powerful tool to enhance and promote psychological and physiological indicators of building occupants.

3. Current study variables

3.1. Biophilia variables adopted for the current study

To investigate the impacts of BDAs on students' well-being, this study adopted BDAs based on two criteria as per below:

The first criterion was to Involve the least studied BADs. Variables were air, animal, fire, naturalistic shapes & forms, biomimicry, and prospects based on the reviewed studies that involved students.

The second criterion was to focus on those BADs that influence physical well-being. Variables were light, plants, water, natural landscape, natural material, the image of nature, natural colors, and simulating natural light & air based on the studies of [13], [28].

3.2. Current study's simulated design

The current study adopted a between-subjects design; a between-subjects design creates two conditions in which the participants are randomly assigned and experience only one of the two conditions. Many researchers use this study type (Yin et al., 2019; Roskams & Haynes, 2020; Valtchanov et al., 2010; McSweeney et al., 2021). The reason is to compare and find out the differences between participants of the two conditions. Another reason is that a between-subject design is time-effective because the participants experience only one condition, which minimizes the duration of the experiment.

3.2.1. Simulated biophilic design

In this condition, the design of the students' room achieved all the biophilic design attributes adopted by the current study as mentioned, which are 1) direct experience of nature which includes Light, Air, Water, Plants, Animals, Natural landscapes, and Fire; 2) indirect experience of nature which includes Images of nature, Natural materials, Natural colors, Simulating natural light and air, Naturalistic shapes and forms, Biomimicry; and 3) experience of space and place which includes prospect and refuge. The design strategies to achieve the adopted biophilic design are clarified in Table 2.

3.2.2. Simulated non-biophilic design

In contrast to the first condition, the design of the student rooms in this condition does not achieve any of the biophilic design attributes adopted by the current. This condition doesn't involve treatment or experience [31], [34], [36]. In this environment, the students will experience a simulated environment with a lack of natural exposure, small windows, lack of outdoor view, artificial ceiling light, and artificial floor and wall material.

3.3. Current Health and physiological well-being

Indoor nature can offer various physical and psychological health benefits [4]. Integration of outdoor nature-based spaces into indoor spaces has health benefits [37]. It is proven that biophilic design has positive effects on health and well-being; these benefits are stress reduction and mental fatigue [38]. The number of indoor plants had statistically significant relationships with occupants' sick leave and health [10]. According to [13], a connection with nature is one of the most influential environmental factors influencing mental health. Several studies demonstrated that a biophilic-designed environment has various health benefits [11], [14], [15], [31], [33], [35], [39]–[41]. However, incorporating nature into interior spaces is rarely regarded as a tool to enhance and promote occupants' health [37]. Health is a state of complete physical, mental and social well-being [42]. this study focuses on physical well-being. [43] stated that there is a link between health and well-being, so as a person becomes healthier, they gain more well-being. Poor physical health usually results in lower classroom productivity [44].

Table 2. Design strategies to achieve the adopted biophilic attributes of the current study [29].

Type of experience			Variables	Design strategies
1	Direct experience of nature	1	Light	Glass walls and reflecting colours and materials
		2	Water	Water tank
		3	Air	Operable windows
		4	Plant	Indoor plants
		5	Animal	Fish tank
		6	Natural landscape	Contact with a natural landscape by the view from a platform(balcony)
		7	Fire	Fireplace
2	Indirect experience of nature	8	Image of nature	Painting
		9	Natural material	wood, stone, wool, cotton
		10	Natural colour	Muted earth tones of soil, rock & plants.
		11	Simulation of natural light and air	mimic the qualities of natural light, variations in airflow,
		12	Naturalistic shapes and forms	Animal facsimiles weaved into fabrics
		13	Biomimicry	From and function found in nature
3	Experience of space and nature	14	Prospect and refuge	Vistas to the outside

4. Methodology

The current study adopted a simulated experiment, To investigate the impact of BDAs on students of university dormitories. Two different rooms have been designed; the first was based on the adopted BDAs called biophilic design room BDR, and the second was Non-biophilic design room NBDR. Participants were randomly divided into two groups and experienced one of the two simulated rooms. The reason for this is to shorten the experiment's duration and compare the data from the two groups. Many researchers adopted this type of research method, such as the studies of (04 Yin et al., 2019; 26 Roskams & Haynes, 2020; 44 Valtchanov et al., 2010; 49 McSweeney et al., 2021).

The current study adopted the simulated environment in this investigation since it has the same influence as the real environment, and this was proved by the researchers who conducted research in real and simulated environments [47], [48].

The current study utilised a virtual reality device (VR) To perform the simulated experiment. VR is essential for studying and understanding restorative effects [47]. Natural elements in a virtual condition can reduce stress [49]. VR allows users to relax [50] and enhances the emotional well-being of those disconnected from the outdoors [51]. Among the modes of Simulation, the current study adopted the Oculus quest2 VR headset, which gives an immersive 360-degree high-resolution view that makes a more enjoyable experience [22]. In addition, The current study will be the first research that adopts a stress induction task (SIT) locally. The aim is to raise stress levels, HR, and BP over what is considered normal [15], [35], [46], [50], [52].

5. Case studies and participants

The experiment was held in university dormitories in Erbil -Iraq. The case studies to be designed as a dormitory building, should be government property and belong to salahaddin university. Based on that, two dormitory buildings were selected for the current study as below:

- **Shahid Shawkat Sheikh Yazdin (SSSY):** This dormitory is located on the main road of the new Erbil-Kirkuk, in the south part of Erbil-Iraq city. The occupants are 1907 male students. SSSY consists of three buildings, and each is five floors. The total number of rooms is 870.
- **18th Shobat girls dormitory (18th SGD):** It is Located on Zank street in Erbil-Iraq. The occupants are 1100 female students. 18th SGD consists of three buildings, and each is three floors. The total number of rooms is 267 rooms.

As part of academic research, the statistician suggested that up to 40 participants are statistically appropriate for this study.

5.1. Data collection (Measurement tool)

The current study measured physical well-being by using bio-monitoring sensors to record the changes in two physiological indicators as below:

5.1.1. HR measure

Measuring HR is one of the most adopted ways to record physiological changes [15], [34], [35], [39], [45], [49]. HR record is preferable due to easy handling, saving time and cost effect. Heart rate is measured by counting beats per minute (BPM) [45]. The average number of HR is between 60 and 100 bpm, as stated by the American Heart Association (AHA) [53], [54].

5.1.2. BP measure

The SBP and DBP are used to monitor blood pressure (SBP and DBP). According to the AHA and American College of Cardiology (ACC), The typical blood pressure range is between 120 millimetres of mercury (mm Hg) systolic and 80 mm Hg diastolic [55].
The current study measured HR and BP by using a digital wrist Bio-metric sensor. The reason for using this medical device is it automatically measures the mentioned physiological indicator an easy to handle.

5.2. Data collection Procedure

The process of experimentation was divided into seven sequential phases:

1. **Preparation**: The overall procedure was explained to the participant, and took information about the VR, Bio-monitoring sensors, and questionnaire.

2. **Survey:** This phase is dedicated to collecting the socio-demographic information of the participants.
3. **Stress induction task:** in this phase, the participants experienced a stressor task; this increased stress levels beyond normal conditions, increased heart rate
4. **Baseline:** in this phase, psychophysiological data were collected from the participants through a bio-monitoring sensor and questionnaire
5. **Simulated experience:** In this stage, the participants were randomly assigned to one of the two conditions
6. **Recovery:** in this phase, psychophysiological data is recollected from the participants after they experience one of the two conditions.

6. Result

The current study measures physiological indicators to investigate the impact of biophilic design on students' well-being. Both groups experienced one of the two simulated designs that randomly has been assigned to them. Physiological indicators have been measured twice (before and the after the experiment). The current study adopted a One-Sample T-Test to identify whether the impact is significant or not.

6.1. Impact of BDAs on students' HR.

The mean HR of the participants of CG was 92.4 b/min before the experiment, and it increased to 97.25 b/min. While The mean HR of the participants of TG was 82.73 b/min before the experiment, and it decreased to 79.52 b/min.
The result of paired samples test indicates that the impact of BDR on students' HR is significant (P < 0.05), and it is a significant positive impact. In contrast, the effect of NBDR on students' HR is significant (P < 0.05), and it is a significant negative impact.

Table 3. Paired-samples statistics of heart rate HR for both groups before and after the experiment [29].

			Paired Samples Statistics			
			Pre-Test	Post-Test	Post-Test	
Var.	TOG	N	Mean	Std.Deviation	Mean	Std.Deviation
HR	CG		92.400	9.150	97.250	11.044
	TG		82.736	6.401	79.526	6.449
			Paired samples Test			
Var.	TOG	N	Mean	Std.Deviation	t-value	Sig. (2-tailed)
HR	CG		-4.850	4.912	-4.415	**0.000**
	TG		3.210	4.340	3.223	**0.004**

Var. Variable; **HR** Heart rate; **TOG** type of group; **CG** Control group; **TG** treatment group;

6.2. Impact of BDAs on students' SBP.

The measure of students' SBP has been changed after the experiment. The measure of CG's SBP was 115.45 mmHg before the experiment and became 120.7 mmHg after the experiment. The TG's SBP was 119 mmHg before the experiment and became 113.57 mmHg after the experiment.
The SBP measure of CG recorded an increase, while the measure recorded less in the TG. Less pressure means less blood pressure on the artery wall, feeling relaxed and nervous.

The result of paired test demonstrates that the impact of BDR on students' SBP is significant (P < 0.05), and it is a significant positive impact. In contrast, the effect of NBDR on students' SBP is significant (P < 0.05), and it is a significant negative impact.

Table 4. Paired-samples statistics of systolic blood pressure SBP for both groups before and after the experiment [29].

			Paired Samples Statistics			
			Pre-Test	Post-Test	Post-Test	
Var.	TOG	N	Mean	Std.Deviation	Mean	Std.Deviation
SBP	CG		115.450	12.881	120.70	11.392
	TG		119.000	13.148	113.57	12.428
			Paired samples Test			
Var.	TOG	N	Mean	Std.Deviation	t-value	Sig. (2-tailed)
SBP	CG		-5.250	6.060	-3.874	0.001
	TG		5.421	10.281	2.298	**0.033**

Var. Variable; **HR** Heart rate; **TOG** type of group; **CG** Control group; **TG** treatment group.

6.3. Impact of BDAs on students' DBP.

DBP is another measure of blood pressure. The measure of CG's DBP was 77.1 mmHg before the experiment and became 80.5 mmHg after the experiment. Contrary, the measure of TG's DBP was 75.13 mmHg before the experiment and became 72.05 mmHg after the experiment. The participants of CG recorded an increase in The DBP measure, while The participants of TG recorded a decrease in The DBP measure. The result of paired samples test indicates that the impact of BDR on students' DBP is significant (P < 0.05), and it is a significant positive impact. In contrast, the effect of NBDR on students' DBP is significant (P < 0.05), and it is a significant negative impact.

Table 5. Paired-samples statistics of diastolic blood pressure DBP for both groups before and after the experiment [29].

			Paired Samples Statistics			
			Pre-Test	Post-Test	Post-Test	
Var.	TOG	N	Mean	Std.Deviation	Mean	Std.Deviation
DBP	CG		77.100	10.637	80.500	8.419
	TG		75.315	9.080	72.052	6.695
			Paired samples Test			
Var.	TOG	N	Mean	Std.Deviation	t-value	Sig. (2-tailed)
DBP	CG		-3.400	6.516	-2.333	**0.030**
	TG		3.263	5.424	2.622	**0.017**

Var. Variable; **HR** Heart rate; **TOG** type of group; **CG** Control group; **TG** treatment group;

7. Conclusion

This study investigated the application of biophilic design and aimed to identify the way that it impacts university students' well-being. Biophilic design as a design approach enhance and promote the connection between human and nature. The design can be used when the connection to natural elements is limited or when the occupants feel stressed and feel discomfort in a specific space. BD has several patterns and attributes, and each one has a particular impact on the occupants of a built environment. These patterns and attributes can be adopted in different ways and techniques. This design is restorative rather than aesthetic value. Therefore, this design approach is ideal when there is a lack of connection with the natural environment, less exposure to natural elements, and occupants feel depressed and discomfort. In this between-subject experiment, two simulated designs were experienced by 39 students of Erbil university dormitories. The first was a BDR, and the second was NBDR. Participants were randomly divided into two groups(TG and CG), and they were assigned to one of the two simulated designs. Their physiological indicators (HR, SBP, and DBP) were measured twice, once before the experiment and the second after the experiment. An automatic Bio-metric sensor is used to record the changes in physiological indicators. The physiological indicators of the participants of TG showed a significant decrease. In contrast, the indicators' measure became more with participants of TG. The result of statistical analysis (paired- Sample T-Test) demonstrates a significantly strong correlation between biophilic design attributes and students' well-being. The physiological indicators of TG Participants decreased, which indicates that the impact is positive. In contrast, the impact was negative because it increased the physiological indicators of CG Participants. In conclusion, BD is a design approach that significantly impacts students' physiological indicators and can be adapted to have a restorative environment.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

Funding source

This study didn't receive any specific funds.

Acknowledgements

We want to thank all participants for their time and the administration staff of both dormitories for their help and support.

REFERENCES

[1] C. S. Hurst, L. E. Baranik, and F. Daniel, "College student stressors: A review of the qualitative research," *Stress Heal.*, vol. 29, no. 4, pp. 275–285, 2013, doi: 10.1002/smi.2465.

[2] W. F. Arsenio and S. Loria, "Coping with negative emotions: Connections with Adolescents' academic performance and stress," *J. Genet. Psychol.*, vol. 175, no. 1, pp. 76–90, 2014, doi: 10.1080/00221325.2013.806293.

[3] A. K. Ibrahim, S. J. Kelly, C. E. Adams, and C. Glazebrook, "A systematic review of studies of depression prevalence in university students," *J. Psychiatr. Res.*, vol. 47, no. 3, pp. 391–400, 2013 doi: 10.1016/j.jpsychires.2012.11.015.

[4] N. van den Bogerd *et al.*, "Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality," *Build. Environ.*, vol. 171, no. June 2019, p. 106675, 2020, doi: 10.1016/j.buildenv.2020.106675.

[5] K. Storrie, K. Ahern, and A. Tuckett, "A systematic review: Students with mental health problems--a growing problem.," *Int. J. Nurs. Pract.*, vol. 16, no. 1, pp. 1–6, Feb. 2010, doi: 10.1111/j.1440-172X.2009.01813.x.

[6] N. Castilla, C. Llinares, J. M. Bravo, and V. Blanca, "Subjective assessment of university classroom environment," *Build. Environ.*, vol. 122, pp. 72–81, 2017, doi: 10.1016/j.buildenv.2017.06.004.

[7] S. Cheryan, S. A. Ziegler, V. C. Plaut, and A. N. Meltzoff, "Designing Classrooms to Maximize Student Achievement," *Policy Insights from Behav. Brain Sci.*, vol. 1, no. 1, pp. 4–12, 2014 doi: 10.1177/2372732214548677.

[8] J. Daly, M. Burchett, and F. Torpy, "Plants in the classroom can improve student performance," *Natl. Inter. Plantscape Assoc.*, no. October, pp. 1–9, 2010.

[9] J. Doxey and T. M. Waliczek, "The Impact of Interior Houseplants in University Classrooms on Course Performance, Course Satisfaction, and Student Perceptions of the Course and Instructor," *HortScience*, vol. 40, no. 4, pp. 1065A – 1065, 2019, doi: 10.21273/hortsci.40.4.1065a.

[10] T. Bringslimark, T. Hartig, and G. G. Patil, "Psychological benefits of indoor plants in workplaces: Putting experimental results into context," *HortScience*, vol. 42, no. 3, pp. 581–587, 2007 doi: 10.21273/hortsci.42.3.581.

[11] A. H. Husein and S. S. Sazgar, "Impacts of Daylight on Improving Healing Quality in Patient Rooms: Case of Shorsh Hospital in Sulaimani City," *Int. Trans. J. Eng. Manag. Appl. Sci. Technol.*, no. May, pp. 0–10, 2020 doi: 10.14456/ITJEMAST.2020.218.

[12] Y. M. Ardiani, A. G. Prawata, and A. Sholihin, "Application of biophilic architecture in apartment design," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 426, no. 1, 2020, doi: 10.1088/1755-1315/426/1/012105.

[13] S. R. Kellert and E. F. Calabrese, "The Practice of Biophilic Design," *Biophilic-Design.Com*, pp. 1–20, 2015, [Online]. Available: www.biophilic-design.com.

[14] T. Gray and C. Birrell, "Are biophilic-designed site office buildings linked to health benefits and high performing occupants?," *Int. J. Environ. Res. Public Health*, vol. 11, no. 12, pp. 12204–12222, 2014 doi: 10.3390/ijerph111212204.

[15] J. Yin, Y. Jing, N. Arfaeir, P. J. Catalona, and josef G. Allen, "Effects of biophilic indoor environment on stress and anxiety recovery between-subjects experiment in virtual reality.pdf," 2019.

[16] D. Putri and T. A. Pawestri, "Effects of Biophilic Virtual Reality Interior Design on Positive Emotion of University Students Responses," *SSRN Electron. J.*, pp. 1–10, 2021, doi: 10.2139/ssrn.3808042.

[17] F. A. Mustafa and F. Radwan, "Towards the application of biophilic parameters in local buildings: A case study of Bilkent School, Erbil City-Iraq," *Int. J. Technol.*, vol. 10, no. 2, pp. 363–375, 2019 doi: 10.14716/ijtech.v10i2.2416.

[18] S. R. Kellert, "Dimensions, Elements, and Attributes of Biophilic Design," in *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*, S. R. 781 Kellert, J. Heerwagen, and M. Mador, Eds. New Jersey: John Wiley & Sons, 2008.

[19] G. Yassein and S. Ebrahiem, "Biophilic Design in the Built Environment to Improve Well-Being: A Systematic Review of Practices," *J. Urban Res.*, vol. 30, pp. 128–146, 2018.

[20] E. Fromm, *The Heart of Man: Its Genius for Good and Evil*. New York: Harper and Row, 1964.

[21] E. O. Wilson, *Biophilia, The Diversity of Life, Naturalist*. 1984.

[22] M. Mollazadeh and Y. Zhu, "Application of virtual environments for biophilic design: A critical review," *Buildings*, vol. 11, no. 4, 2021, doi: 10.3390/buildings11040148.

[23] S. R. Kellert, "Building for life: Designing and understanding the human-nature connection," *Renew. Resour. J.*, vol. 24, no. 2, 2005.

[24] R. Berto and G. Barbiero, "The Biophilic Quality Index. A Tool to Improve a Building from 'Green' to Restorative.," *Visions Sustain.*, vol. 0, no. 8, pp. 38–45, 2017, doi: 10.13135/2384-8677/2333.

[25] P. H. Kahn, "Developmental Psychology and the Biophilia Hypothesis: Children's Affiliation with Nature," *Dev. Rev.*, vol. 17, no. 1, pp. 1–61, 1997, doi: 10.1006/drev.1996.0430.

[26] M. Richardson and C. W. Butler, "Nature connectedness and biophilic design," *Build. Res. \& Inf.*, vol. 0, no. 0, pp. 1–7, 2021, doi: 10.1080/09613218.2021.2006594.

[27] H. C. Lee and S. J. Park, "Assessment of importance and characteristics of biophilic design patterns in a children's library," *Sustain.*, vol. 10, no. 4, 2018, doi: 10.3390/su10040987.

[28] W. Browning, C. Ryan, and J. Clancy, "14 Patterns of Biophilic Design: Improving Health & Well-Being in the Built Environment," *Terrapin Bright Green,LLC*, pp. 1–60, 2014, doi: 10.1016/j.yebeh.2008.04.024.

[29] M. Woo, P. MacNaughton, J. Lee, B. Tinianov, U. Satish, and M. Boubekri, "Access to Daylight and Views Improves Physical and Emotional

Wellbeing of Office Workers: A Crossover Study," *Front. Sustain. Cities*, vol. 3, no. September, pp. 1–13, 2021, doi: 10.3389/frsc.2021.690055.

[30] M. Roskams and B. Haynes, "A randomised field experiment to test the restorative properties of purpose-built biophilic 'regeneration pods,'" *J. Corp. Real Estate*, vol. 22, no. 4, pp. 297–312, 2020, doi: 10.1108/JCRE-05-2020-0018.

[31] Y. Al-Dmour, V. Garaj, and D. Clements-Croome, "The flourishing of Biophilic workplaces: 'Second Home' offices as a case study," *Intell. Build. Int.*, vol. 0, no. 0, pp. 1–14, 2020, doi: 10.1080/17508975.2020.1807895.

[32] S. Topgul, "The Impact Of Biophilic Designs On Worker Efficiency," *J. Soc. Res. Behav. Sci.*, vol. 4, no. 6, pp. 232–239, 2018, [Online]. Available: www.contentmarketinginstitute.com.

[33] J. McSweeney, S. Johnson, S. Sherry, J. Singleton, and D. Rainham, "Indoor nature exposure and influence on physiological stress markers," *Int. J. Environ. Health Res.*, vol. 31, no. 6, pp. 636–650, 2021 doi: 10.1080/09603123.2019.1679357.

[34] J. J. Alvarsson, S. Wiens, and M. E. Nilsson, "Stress recovery during exposure to nature sound and environmental noise," *Int. J. Environ. Res. Public Health*, vol. 7, no. 3, pp. 1036–1046, 2010 doi: 10.3390/ijerph7031036.

[35] B. Grinde and G. G. Patil, "Biophilia: Does visual contact with nature impact on health and well-being?," *Int. J. Environ. Res. Public Health*, vol. 6, no. 9, pp. 2332–2343, 2009, doi: 10.3390/ijerph6092332.

[36] J. Mcsweeney, D. Rainham, S. A. Johnson, S. B. Sherry, and J. Singleton, "Indoor nature exposure (INE): A health-promotion framework," *Health Promot. Int.*, vol. 30, no. 1, pp. 126–139, 2015, doi: 10.1093/heapro/dau081.

[37] A. A. Brielmann, N. H. Buras, N. A. Salingaros, and R. P. Taylor, "What Happens in Your Brain When You Walk Down the Street? Implications of Architectural Proportions, Biophilia, and Fractal Geometry for Urban Science," *Urban Sci.*, vol. 6, no. 1, p. 3, 2022 doi: 10.3390/urbansci6010003.

[38] C. Y. Chang and P. K. Chen, "Human response to window views and indoor plants in the workplace," *HortScience*, vol. 40, no. 5, pp. 1354–1359, 2005, doi: 10.21273/hortsci.40.5.1354.

[39] V. I. Lohr, C. H. Pearson-Mims, and G. K. Goodwin, "Interior Plants May Improve Worker Productivity and Reduce Stress in a Windowless Environment," *J. Environ. Hortic.*, vol. 14, no. 2, pp. 97–100, 1996 doi: 10.24266/0738-2898-14.2.97.

[40] S. Y. Park, J. S. Song, H. D. Kim, K. Yamane, and K. C. Son, "Effects of interior plantscapes on indoor environments and stress level of high school students," *J. Japanese Soc. Hortic. Sci.*, vol. 77, no. 4, pp. 447–454, 2008, doi: 10.2503/jjshs1.77.447.

[41] World Health Organization, *Basic documents*. World Health Organization, 2020.

[42] A. Zautra and A. Hempel, "Subjective well-being and physical health: a narrative literature review with suggestions for future research.," *Int. J. Aging Hum. Dev.*, vol. 19, no. 2, pp. 91–110, 1984, doi: 10.2190/a9rb-7d02-g77k-m3n6.

[43] M. Felez-Nobrega, C. H. Hillman, E. Cirera, and A. Puig-Ribera, "The association of context-specific sitting time and physical activity intensity to working memory capacity and academic achievement in young adults," *Eur. J. Public Health*, vol. 27, no. 4, pp. 741–746, 2017, doi: 10.1093/eurpub/ckx021.

[44] L. Reynolds *et al.*, "Virtual Nature as an Intervention for Reducing Stress and Improving Mood in People with Substance Use Disorder," *J. Addict.*, vol. 2020, pp. 1–7, 2020, doi: 10.1155/2020/1892390.

[45] D. Valtchanov, K. R. Barton, and C. Ellard, "Restorative effects of virtual nature settings," *Cyberpsychology, Behav. Soc. Netw.*, vol. 13, no. 5, pp. 503–512, 2010, doi: 10.1089/cyber.2009.0308.

[46] S. F. Kuliga, T. Thrash, R. C. Dalton, and C. Hölscher, "Virtual reality as an empirical research tool - Exploring user experience in a real building and a corresponding virtual model," *Comput. Environ. Urban Syst.*, vol. 54, pp. 363–375, 2015, doi: 10.1016/j.compenvurbsys.2015.09.006.

[47] A. Chirico and A. Gaggioli, "When Virtual Feels Real: Comparing Emotional Responses and Presence in Virtual and Natural Environments," *Cyberpsychology, Behav. Soc. Netw.*, vol. 22, 2019 doi: 10.1089/cyber.2018.0393.

[48] J. Yin, S. Zhu, P. Macnaughton, J. G. Allen, and J. D. Spengler, "Physiological and cognitive performance of exposure to biophilic indoor environment," *Build. Environ.*, vol. 132, no. January, pp. 255–262, 2018, doi: 10.1016/j.buildenv.2018.01.006.

[49] A. P. Anderson, M. D. Mayer, A. M. Fellows, D. R. Cowan, M. T. Hegel, and J. C. Buckey, "Relaxation with immersive natural scenes presented using virtual reality," *Aerosp. Med. Hum. Perform.*, vol. 88, no. 6, pp. 520–526, 2017, doi: 10.3357/AMHP.4747.2017.

[50] M. H. E. M. Browning, K. J. Mimnaugh, C. J. van Riper, H. K. Laurent, and S. M. LaValle, "Can Simulated Nature Support Mental Health? Comparing Short, Single-Doses of 360-Degree Nature Videos in Virtual Reality With the Outdoors," *Front. Psychol.*, vol. 10, no. January, pp. 1–14, 2020 doi: 10.3389/fpsyg.2019.02667.

[51] N. L. Yeo *et al.*, "What is the best way of delivering virtual nature for improving mood? An experimental comparison of high definition TV, 360° video, and computer generated virtual reality," *J. Environ. Psychol.*, vol. 72, p. 101500, 2020, doi: 10.1016/j.jenvp.2020.101500.

[52] J. W. Mason, D. J. Ramseth, D. O. Chanter, T. E. Moon, D. B. Goodman, and B. Mendzelevski, "Electrocardiographic reference ranges derived from 79,743 ambulatory subjects," *J. Electrocardiol.*, vol. 40, no. 3, pp. 228-234.e8, 2007, doi: https://doi.org/10.1016/j.jelectrocard.2006.09.003.

[53] P. Kansara, R. Dhar, R. Shah, D. Mehta, and P. Raut, "Heart Rate Measurement," *J. Phys. Conf. Ser.*, vol. 1831, no. 1, 2021, doi: 10.1088/1742-6596/1831/1/012020.

[54] J. M. Flack and B. Adekola, "Blood pressure and the new ACC/AHA hypertension guidelines," *Trends Cardiovasc. Med.*, vol. 30, no. 3, pp. 160–164, 2020, doi: 10.1016/j.tcm.2019.05.003.