Biophilic design for remote studying environments: analysis of case studies involving a collaboration between ergonomics and environmental psychology

Giovanni Inglese[1], Alessandro Lorenzo Mura[2], Susana Alves[2], Marino Bonaiuto[2], Teresa Villani[1]

[1]Department of Planning, Design, and Technology of Architecture, Sapienza University of Rome, Italy
giovanni.inglese@uniroma1.it
teresa.villani@uniroma1.it
[2]Department of Developmental and Social Psychology, Sapienza University of Rome, Italy
Department of Psychology of Development and Socialisation Processes, Sapienza University of Rome, Italy
alessandrolorenzo.mura@uniroma1.it
s.alves@uniroma1.it
marino.bonaiuto@uniroma1.it

Abstract

In our post-industrial society, although the remarkable technological advancement allows us endless possibilities, the maturity of the debate on environmental sustainability requires new design, production and consumption strategies, and a radical revision of the concept of development. Our lifestyles increasingly lead us to spend much of our time indoors, and this condition, exacerbated by conflicts and pandemic, has turned the spotlight on the importance of accessibility to the natural environment, put in risk by growing urbanization and global urban population, the upscaling of environmental degradation and the challenges posed by climate change. In this context, Designers are challenged to question new ways of establishing connections with nature that will contribute to mitigate, cope, and adapt to environmental and societal challenges while at the same time helping people to develop new capabilities in their given contexts. Biophilic Design emphasizes the need to maintain, enhance and restore the beneficial experience of nature in the built environment. Even if it's based on scientific evidence from several studies in the fields of psychology, medicine and social sciences, which demonstrate that exposure to natural environments or related elements has a positive impact on human health, further reflections are needed on how these inputs can be embodied in environments and artifacts by the Design disciplines. Based on these assumptions, the theme of the Psychology and Cognitive Ergonomics course within the bachelor's degree program in Industrial Design at Sapienza University of Rome was developed. Through an interdisciplinary approach Human-Centred Design and Environmental Psychology were combined to enquire about the use of biophilic elements within remote studying environments, a widely used practice following the closures of schools and universities caused by the Covid-19 pandemic. A combination of methods and tools from both disciplines were used to test Biophilic Design hypotheses that, on the one hand, ensure optimal ergonomic usability and, on the other hand, through their regenerative qualities, promote psychological well-being and reduce stress symptoms related to remote study activities and social isolation. The analysis of these case studies allowed us to reflect on Biophilic Product Design and their role in remote studying environments. We conclude by advocating the use of interdisciplinary practices in which Design, combined with Environmental Psychology becomes a promoter of more desirable domestic environments and of a future in which a symbiotic relationship with nature is established.

Author keywords

Biophilic Design, Human-Centred Design, Remote Studying, Environmental Psychology

Introduction

The growing urbanization and the continuous increase of the world's urban population have led to a direct and indirect (McDonald et al., 2020) impact on biodiversity (Turner et al., 2004). Environmental degradation and the challenges of climate change make access to greenery and nature a restricted privilege. In today's 'indoor generation,' most human activities occur within an enclosed space (Kelly & Fussel, 2019). This condition has been further exacerbated by the conflicts our society is experiencing and the global pandemic. Following the drastic incidence of Covid-19 since March 2020, the Italian government has implemented strict measures to stem the pandemic spread through rigid lockdowns. Since the pandemic, the world of work has radically changed, with a massive reliance on remote working for all those activities that did not require an unavoidable work presence. However, one of the areas most affected by the implementation of restrictive measures was the educational sector. All Italian schools and universities were forced to implement distance learning (e-learning or remote learning) throughout the most acute phase of the emergency. This forced transition has

entailed not only a restructuring of teaching methods, now characterized by the unavoidable use of digital technologies and means of communication (such as Zoom, Teams, Meet, etc.) but to a complete restructuring of home environments, now dedicated to the activity of studying or working remotely. In addition to this, of course, one of the main consequences of lockdowns has been the inability to leave except for stringent reasons (Corley et al., 2021; Dzhambov et al., 2021), thus limiting people's ability to have contact with natural environments (e.g., Garrido-Cumbrera et al., 2022; Mintz et al., 2021). Therefore, finding strategies to implement natural elements within the home environment became necessary.

The biophilia theory and biophilic design

The term "biophilia" can be summarized as "the innately emotional affiliation of human beings to other living organisms" (Wilson, 1993, p. 31). The concept was introduced by Erich Fromm (1964/1976) and has been popularised in the work of Kellert & Wilson (1993), who affirm that human evolutionary history has produced "the innate tendency to focus on life and lifelike processes" and the need to "affiliate with other forms of life". Biophilia has been conceptualized as a sign of mental and physical health, with supporting evidence showing that natural settings (compared to built settings) are preferred and lead to positive health outcomes, such as restoration from mental fatigue and stress. Building on the theory of biophilia, the biophilic design seeks to use nature in the design of indoor and outdoor environments (as well as in the design of artifacts) to promote people's health and well-being. Biophilic Design stresses the need to maintain, improve and restore the beneficial experience of nature in the built environment. It represents a sustainable approach with financial advantages across healthcare, education, retail, workplace, and community environments (Browning et al., 2012). Kellert & Calabrese (2015) have proposed design strategies for successfully applying biophilic design in diverse contexts, such as educational settings (Alves, Betrabet Gulwadi & Nilsson, 2022). The basic components of the biophilic design framework are: direct (e.g., having indoor plants), indirect experience of nature (e.g., watching nature), and the experience of space and place (e.g., prospect and refuge). Drawing from empirical evidence, biophilic design patterns are not formulas; they are hypotheses to be tested and should be thought of as another tool in the designer's toolkit - meant to inform, guide, and assist in the design process (Ryan et al., 2014).

The psychological impact of biophilic design

Biophilia is one of the aspects most touched upon in the study of this predisposition concerns the natural elements directly or indirectly experienced by the individual. The positive effect of exposure to natural environments and stimuli in promoting psychological well-being has been widely studied (Bratman et al., 2019). The term restoration refers to the recovery or regeneration of mental resources used in daily activities (Harting, 2004). The two main theories concerning restorativeness are the attention restoration theory (ART; Kaplan & Kaplan, 1989), according to which natural environments do not require direct attentional effort, thus allowing for a reduction in the use of cognitive resources (Jiang et al., 2020), and the stress recovery theory (SRT; Urlich, 1983), which draws on a psycho-evolutionary perspective, and postulates that the natural environment allows for a reduction in arousal and stress levels (Chang et al., 2021). Direct experience in natural environments is not the only strategy to activate the regenerative process. Implementing natural elements (real or reproduced) in indoor environments through biophilic design can allow one to experience effects similar to those activated by immersion in natural environments. Natural or artificial light with similar characteristics, implementation of natural materials such as wood or stone, natural sounds, and implementation of indoor plants or other reproductions of natural environments are just some of the elements most frequently found in the literature (Bolten & Barbiero, 2020; Browing et al., 2014; Kellert, 2008; 2018; Sturgeon, 2017). Research based on the implementation of biophilic design has reported results consistent with the literature on restorativeness in natural environments (Aristizabal et al., 2021; Cole et al., 2021; Determan et al., 2019; Jiang et al., 2021; Yin et al., 2020), thus confirming the possibility of being able to effectively integrate these types of elements into built and indoor environments as well, with positive effects on psychological well-being.

Aim of the study

Based on these assumptions, this paper intends to report an empirical study promoted during the Psychology and Cognitive Ergonomics course within the bachelor's degree program in Industrial Design at Sapienza University of Rome. Through an interdisciplinary approach, Human-Centred Design and Environmental Psychology set out to promote the use of Biophilic Design to improve remote studying environments, a widely used practice following the closures of schools and universities caused by the pandemic by Covid-19. The aim is to illustrate a possible methodology within Design education and to bring to greater maturity the reflections on Biophilic Product Design to extend our scientific community's knowledge and promote interdisciplinary practices.

Method

Participants

The research sample comprised 521 college students from different Italian universities who voluntarily completed the questionnaire. They were aged 18 to 38 (M = 20.93; SD = 2.20); 232 were men (44.5%), 282 were women (54.1%), and 7 preferred not to answer (1.4%). 466 students were enrolled in a bachelor's or single-cycle degree program (89.4%) and 55 in a master's degree program (10.6%).

Tools and procedure

The research was conducted in full compliance with the Ethical Principles of Psychologists and Code of Conduct of the American Psychological Association (APA) and was authorized by the Ethics Committee of the Sapienza University of Rome. The study was conducted in April 2022, when Italian universities, due to the Covid-19 pandemic, continued implementing a hybrid teaching mode with in-person and remote lectures. During an initial administration, participants were asked to think about the home environment where they performed their remote study activities (didactic or self-study) and to complete a self-report questionnaire. The first instrument was the Perceived biophilic qualities in remote studying (ad hoc): the measure includes 19 items referred to the main sources of Biophilia found in the literature (e.g., Bolten & Barbiero, 2020; Browning et al. 2014; Kellert, 2008; Kellert 2018;

Table 1. escriptive statistics, bivariate correlations and Alpha in diagonal. Descriptive statistics, bivariate correlations and Cronbach's Alpha in diagonal.

Variable	N	M	SD	S	K	1	2	3	4	5	6	7
1. General Perceived Biophilia	521	3.20	.61	-.03	-.01	.81						
2. Direct Experience	521	3.65	.69	-.36	-.01	.89***	.81					
3. Indirect Experience	521	2.39	.81	.43	.02	.58***	.22***	.88				
4. Prospect and Refuge	521	3.19	1.23	-.02	-.86	.73***	.60***	.15***	.72			
5.Restorativeness	521	3.27	.72	-.18	.12	.41***	.36***	.25***	.25***	.72		
6. Engagement	521	4.43	.95	-.39	.17	.18***	.15***	.12**	.12**	.26***	.88	
7. Stress	521	2.35	.41	.16	.36	-.08*	-.10*	-.04	-.02	-.18***	-.08	.75

Note: * = p < .05; ** = p < .01; *** = p < .001; M = Mean; SD = Standard deviation; S = Skewness; K = Kurtosis.

Sturgeon, 2017) divided into the 3 categories identified by Kellert and Calabrese (2015), namely direct experience with nature (10 items; Alpha = .81), indirect experience (6 items; Alpha = .68), and the experience of space and place (3 items; Alpha = .88). Also, an overall perceived Biophilia score was calculated (Alpha: .82). The psychological variables concernedPerceived restorativeness (5 items; Alpha: .72; Korpela et al. 2008),Student Engagement (UWES-9; 9 items; Alpha: .88; Schaufeli & Bakker, 2003; 2004),and Student Stress - Effort-Reward Imbalance student questionnaire (12 items; Alpha: .75; Wege et al., 2017) For all these measures, the response scales consist of a 5-step Likert scale (from 1 = "Completely disagree" to 7 = "Fully agree"), except for the Engagement rating scale, for which a 7-step Likert from "never" to "always" was used. Socio-demographic data (gender, age, and degree course level) were also collected. The same participants were asked to fill out a second questionnaire containing an ergonomic checklist for objectively assessing all the biophilic elements with which they relate, directly or indirectly, during remote studying activity and that, therefore, could contribute to their satisfaction and requirements needs related to certain needs classes such as Safety, Well-being, Usability, Appearance, Management (UNI 8289:1981). For each requirements class, the requirements classes have been identified (UNI 8290-2:1983) to which the items of the Checklist refer by proposing questions for the verification of the qualitative and quantitative characteristics of the elements observed, starting from minimum inclusive safety performance (Villani et al., 2021) thresholds defined by regulatory references related to health and safety at work agile (L. n. 81/2017, art. 18-23), to the usability (D.M. 236/89) and from "good technique" criteria correlated with people anthropometric data.

Results

Relationship between perceived biophilic qualities and psychological variables

Jamovi v.2.2.5 statistical software was used to analyze frequencies, descriptive statistics, and correlations among psychological variables. The mean scores, univariate normality, and bivariate correlations between the variables under research are shown in Table 1. According to the skewness and kurtosis values, which are all between -1 and +1, the normality assumption was not violated. From the correlation analysis, the overall indicator of perceived Biophilia was found to be correlated with perceived restorativeness (r = 0.41; p < .001), engagement (r = 0.18; p < .001), and stress (r = -0.08; p < .05), demonstrating how the perception of natural elements can help regenerate students' cognitive resources, promoting their engagement in the educational activity, by reducing stress-related symptoms. Regarding the specific sources of Biophilia, direct experience of natural elements, whether internal or external to the study environment, reported the highest correlation indices, correlating positively with restorativeness (r = 0.36; p < .001) and engagement (r = 0.15; p < .001) and negatively with stress (r = -0.10 < .05). Indirect experience with nature, prospect, and refuge reported same correlation indices with restorativeness (r = 0.25; p < .001) and engagement (r = 0.12; p < .01). Unexpectedly these two sources of perceived biophilia did not correlate with perceived stress (r = -0.04; p = n.s.) (r = -0.02; p = n.s.).

Objective perception of biophilic-related elements

The ergonomic checklist results about biophilic elements have been analyzed on three levels: biophilic elements in general (one general index), level of individual needs classes (6 indices), and level of individual requirement classes (15 indices). Each of these three refers to the individual elements of

Table 2. Ergonomic checklist results about the biophilic element

Class	Yes	No	NR
Needs class - Security	32%	57%	11%
Requirement class – Fire safety	30%	58%	12%
Requirement class - Safety of use	34%	56%	10%
Needs class - Well-being	35%	36%	29%
Requirements class – Thermal comfort	41%	21%	37%
Requirements class - Acoustic well-being	28%	55%	17%
Requirements class - Visual well-being	51%	38%	11%
Requirements class - Olfactory well-being	46%	47%	7%
Needs class – Usability	45%	37%	18%
Requirements class - Accessibility	14%	56%	30%
Requirements class - Furnishability	58%	23%	19%
Requirements class - Furnishability	58%	23%	19%
Requirements class - Flexibility	41%	50%	9%
Requirements class - Usability	45%	40%	15%
Requirements class - Communicativeness	84%	9%	7%
Needs class – Appearance	41%	47%	12%
Needs class – Privacy	38%	49%	13%
Requirements Class - Spatial Privacy	55%	31%	14%
Requirements Class - Functional Privacy	20%	66%	14%
Needs class – Management	77%	16%	12%
Requirements Class - Maintainability	65%	22%	13%
Requirements Class - Cleanability	79%	10%	11%

the checklist that, aggregated, return these summary indices. Generally, it has emerged that inside the remote study sites/workstations, there are no biophilic elements in 40% of cases inside the remote study sites/workstations. The results of the other two levels are shown in Table 2.

Examples of biophilic design

The psychological and ergonomic results were subsequently considered as a basis for developing the design proposals. The ergonomic approach to the project, with its ability to evaluate the multiplicity of variables that define the interaction between people and what they relate to (Tosi, 2018), has been combined with the philosophy of Human Centered Design. The biophilic design solutions presented by students vary in the use of materials, shapes, and textures in their aim to stimulate sensory perception, improve well-being and meet ergonomic requirements. Moreover, to prevent the solutions of these new designers from being replaced by superficial imitations, a more holistic and sustainable approach has been stimulated (Stevens et al., 2020), promoting the use of solutions respectful of Nature and also from the point of view of materials and production processes.

The data collected by the Ame group showed that as the appearance variable increases, the level of perceived stress decreases while the person's interest increases. On the other hand, an increase in olfactory well-being, linked to air quality, leads to a psychological reduction in stress. Finally, good usability within the smart studying workplace positively influences the subject's performance, increases well-being and engagement, and reduces stress and burnout. They proposed a cactus-shaped desk module that performs several functions, including tidying up cables, pen holders, and air freshener. This product is intended to improve classes of needs such as Safety, Wellness, Usability, and Management, stimulating the perception of natural elements on different sensory levels. The material they use for production is Ecoallene, derived from the processing and recycling of poly-bonded waste, which is colorable, versatile, infinitely recyclable, and suitable for various types of molding.

Instead, the Palma group, in order to improve their situation, worked on the correlation of ergonomic well-being on mental and physical health and on how colors and materials reminiscent of nature increase the sense of belonging to a place and, consequently, the desire to spend more time there. So they designed Ceppo, a footrest whose materials and shapes recall a tree trunk. In particular, it improves the ergonomics of the study station and stimulates sight and touch during the remote study activity through natural materials such as wood and stabilized lawns.

The Cinquis group started from the point of view of implementing acoustic well-being, usability, appearance, and safety, which were found to be lacking in the questionnaire, and from the psychological point of view, improved direct experience with nature, in particular through sound, because of the direct effects they have on restorativeness and engagement. They worked on evoking nature at a sound level, designing a speaker that recalls the organic shapes of a shell, also associating on a semantic level the act of bringing the shell to the ear to listen to the sea. In addition to reminding marine environments, the speaker emits white noises that stimulate concentration during one's study time.

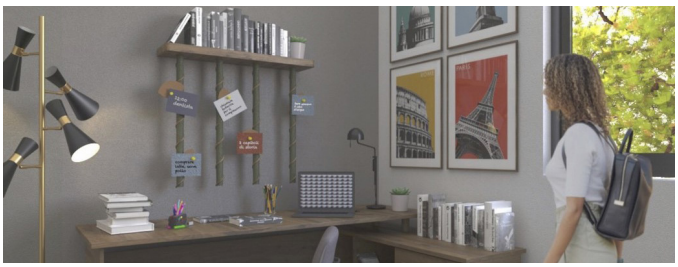

Figure 1. Jungle-IT by Marmotas, rendering

In the last case, however, the ergonomics checklist showed that visual comfort, usability, accessibility, and flexibility were lacking, so they implemented them in their remote studying station. From a psychological point of view, they instead worked on enhancing the indirect experience with nature through shapes and colors, as it increases the organizational potential of the user, the positive relationship between the user and the room, and a general sense of security. So, with the *Jungle-IT* (Figure 1), Marmotas group brings the jungle into the remote study station. The system, consisting of simple elements such as wooden profiles, rope, cork leaves, and S-shaped steel hooks, offers the possibility of a support/shelf where to place books and also serves as a bulletin board, allowing to reorder sheets and notes.

Conclusion

In conclusion, this study shows the positive impact of using natural elements in promoting ergonomic and psychological well-being in remote studying settings. Design, with its ability to act both on a micro- and macro-scale, can encourage the implementation of biophilic elements, particularly in those contexts where direct contact with green spaces has been diminished, such as in large cities or metropolises, but also extreme context like the Fourth Environment. It can help to cope with traumatic and unpredictable events, such as the Covid-19 pandemic and conflicts, that makes immersion in green spaces difficult. The collaboration between two different perspectives, such as Psychology and Design, shows how Biophilic Design can be put into practice: it allows both the analysis of objective requirements for design and the consideration of students' subjective needs and perceptions. The benefit of this interaction is that it allows the construction of more desirable remote studying environments centered on humans and their real needs and a symbiotic relationship with nature. Biophilia alone is not enough to generate automatically sustainable solutions in this context. It is therefore important to provide constant input to students on how to make this reconnection with nature not only aesthetic but the result of a conscious practice at every level. To face today's challenges, using the green "as a sole legitimization of an otherwise unsustainable project is not enough," as Celine Baumann states (Block, 2019). There is, therefore, a need to find more holistic and enlightening solutions by broadening the scope and examining the challenge in a wider context and at different scales (Scalisi & Ness, 2022). Developing a new unity with nature is necessary, a paradigm shift from "human on nature" to "human and nature".

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