

Review

The State of the Art in the Biophilic Construction of Healthy Spaces for People

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Abstract: Human beings need a connection to nature for their overall well-being, as highlighted by numerous publications. Housing is an extension of people's lives. Confinement due to the COVID-19 pandemic, the rise of sustainability, longevity and the digital society are placing value on more sustainable and healthy construction for people's well-being and quality of life. These premises motivate this study of the state of the art of biophilic design with a therapeutic and social approach. The main objective of this research is to investigate the evolution of the concept of biophilia in healthy buildings for people and the environment, analysing the current situation and identifying the main theories, models and applications. This research employs the six-step methodology for state-of-the-art analysis (SotA), using the process of reflexivity throughout this study. There are very few scientific studies that measure the positive impact of biophilic design on people's well-being, and they tend to take the form of scientific discussion rather than evidence; this is their main limitation. Our recommendation is to identify new quantitative research on the biophilic impact on humans of healthy spaces in order to evaluate their effects.

Keywords: healthy spaces; sustainability; well-being



Citation: Buceta-Albillos, N.; Ayuga-Téllez, E. The State of the Art in the Biophilic Construction of Healthy Spaces for People. *Buildings* **2024**, *14*, 491. <https://doi.org/10.3390/buildings14020491>

Academic Editor: Paulo Santos

Received: 28 November 2023

Revised: 24 January 2024

Accepted: 30 January 2024

Published: 9 February 2024



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1. Introduction

Human beings have been connected to the natural environment since their origin as *Homo sapiens*, according to the Savanna Principle [1]. People are particularly attracted to the natural environment and to natural light, which brings important physiological and psychological benefits [2]. Being in connection with the environment, the immune system is related to the nervous and hormonal systems, so the relationship with the environment conditions physical feelings and emotions [3].

During the COVID-19 confinement, people felt the need to turn to the natural environment as a restorative response to the cognitive, psychological and physiological states produced during the pandemic. The current context is that the outcome of the pandemic demonstrates that people place value on natural spaces [4,5]. More than 90 days of confinement is enough to appreciate the benefits of being in contact with nature and to reflect on the place in which one lives [6]. Edward O. Wilson, who in 1984 [7] highlighted the importance for people of being in contact with nature, defined biophilia as the tendency to seek a connection with nature.

The urban population is expected to grow from 56% of the global total in 2021 to 68% by 2050 [8]. Although in the early phases of the COVID-19 pandemic, there was a trend towards living in rural areas, which were perceived to be safer, this does not alter the course of global urbanisation, according to the World Cities Report 2022 [9].

Most of the sources studied confirm that we spend more than 90% of our time in indoor spaces. According to a Velux study, 'Let Nature back into your life' [10], 52% of Spaniards spend less than one hour a day in contact with nature. The absence and disconnection from green areas has had a major impact on quality of life, as became evident during the pandemic, and there are now more cases of depression and anxiety [11].

The current post-COVID-19 understanding of health-related well-being and quality of life looks at healthy spaces for people, and the construction of biophilic design has emerged to enhance well-being through mental and physical health. Biophilic design is based on the concept of biophilia [7], which is applied to the construction sector to achieve the best health outcomes thanks to the benefits of being in contact with nature [12]. That is the principal research hypothesis for this study.

The main objective of this research is to investigate the evolution of the concept of biophilia in construction in the current climate of interest in people's well-being and improvements in their quality of life. Additional goals are to identify the common aspects of biophilic design and the main gaps, applications and evidence of its benefits for well-being, as well as new lines for future study.

2. Materials and Methods

The methodology applied in this qualitative research is based on the six steps of state-of-the-art analysis (SotA) [13]. The SotA method promotes awareness of the subject of this study with a critical spirit and opens new horizons for future lines of research.

This SotA method supports the analysis of the evolution of biophilic design with a reflexivity process, providing important benefits for this topic. The SotA method is summarised in Figure 1 below (figure created by the authors).

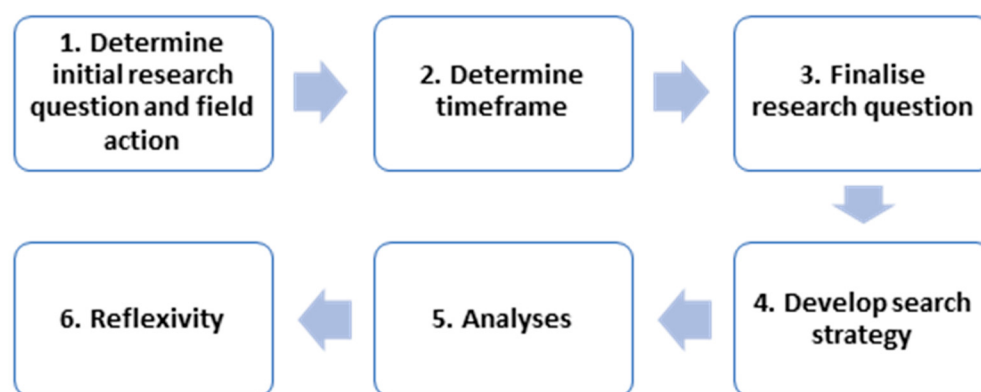


Figure 1. The six-step methodology for state-of-the-art analysis (SotA).

Reflexivity is used as a tool for the analytical process, especially for the discussion and conclusions of this research. Reflexivity involves a concrete, critical, subjective and dynamic awareness of the research objective and helps in the identification of the appropriate literature and the interpretation of the data [14,15].

A review of the existing literature is necessary to gain a better understanding of the context and the research question.

Firstly, a study was carried out of the existing bibliography on the benefits for human well-being of contact with nature, identifying a long list of scientific articles, books and journals of interest (more than 3700 documents were found, of which 240 were selected and 121 analysed).

Secondly, a search for more specific information was conducted in relation to the biophilic design of healthy spaces for people (76 documents analysed and referenced in this manuscript). Some recent studies review the subject of biophilic construction using the PRISMA method [16–19], and include a new SotA method to identify future lines of research.

Tables 1 and 2 show the data summary of the literature review, which was the source of the first and second searches.

Table 1. First search: benefits of contact with nature for human well-being; 3700 documents found, 240 selected, 121 analysed.

Sources (121 Documents)	% References	Main Journal	% References in Source
Elsevier	25%	<i>Journal of Environmental Psychology</i>	86%
Spain Journals	19%	<i>Revista de investigaciones geográficas</i>	44%
MDPI	9%	<i>Sustainability</i>	88%
Taylor & Francis	7%	<i>Journal of Ecosystem Health and Sustainability</i>	50%
Other sources	40%		

Table 2. Second search: the biophilic design of healthy spaces; 76 documents related to the research objective.

Sources of 76 Documents	References
Conferences and Congresses	9%
Web	9%
Books	7%
WHO	5%
<i>Buildings</i>	5%
<i>Journal of Environmental Psychology</i>	4%
<i>Sustainability</i>	4%
GBCe	4%
Cambridge: Harvard University Press	3%
Terrapin Bright Green	3%
<i>Journal of Cleaner Production</i>	3%
ONU Habitat	3%
Other journals	13%
Other bibliography	29%

3. Results

The results of each of the six phases of the methodology applied for the state-of-the-art analysis for the objective of this study are detailed below (Table 3).

Table 3. The six steps of the state-of-the-art analysis (SotA) applied to the research topic.

SotA Step	To the Topic
3.1. Determine initial research question and field of review	3.1.a. Question to be answered: the contribution of biophilic design to holistic well-being. 3.1.b. Field of action: healthy buildings.
3.2. Determine timeframe	3.2.a. Scope of the research: to determine the factors that influence healthy construction in contact with nature. 3.2.b. Key milestones in the evolution of biophilic designs. 3.2.c. How does the evolution of biophilia in building justify its study?
3.3. Finalise research question to reflect timeframe	3.3.a. How can the scope of the research change the initial research question? 3.3.b. How does the information sought actually answer the question?
3.4. Develop search strategy to find relevant manuscripts	3.4.a. How far am I from knowing the current situation of the target of the study? 3.4.b. Do the information sources help to answer the question posed?

Table 3. Cont.

SotA Step	To the Topic
3.5. Analyses	3.5.a. Main articles consulted 3.5.b. Common points 3.5.c. Assumptions 3.5.d. Main gaps 3.5.e. Contradictions 3.5.f. Applications 3.5.g. Current reference models 3.5.h. Future research lines
3.6. Interpretation of the results	3.6.a. Evolution and current situation of biophilic construction.

3.1. Determine the Initial Research Question and Field of Review, in Two Actions

- 3.1.a. Question to be answered: the contribution of biophilic design to holistic well-being.
- 3.1.b. Field of action: healthy buildings.

3.2. Determine the Timeframe in Three Phases

3.2.a. Scope of the research: to determine the factors that influence healthy construction in contact with nature.

International agencies are focusing on the promotion of healthy environments to ensure the health of the population, especially in the wake of the COVID-19 pandemic [20]. The WHO's approach to the causal model of urban green impact on health and well-being can be seen at the local level with the design of urban environments that produce health [21]. Integral health (physical, mental and social) depends on where people develop, grow, live and work. Therefore, the aim of the research is to identify, understand and assess the factors that determine whether a building can be considered healthy in contact with nature.

3.2.b. Key milestones in the evolution of biophilic design

As long ago as 1850, the British nurse Florence Nightingale [22] demonstrated how elements related to nature, such as the pleasant arrangement of space, have a physical and psychological effect on patients' recovery process.

Some years later, in 1898, the British urban planner Ebenezer Howard wrote the utopian Garden City model entitled "To-morrow: A Peaceful Path to Real Reform", reprinted in 1902 as "Garden Cities of Tomorrow". The Garden City is an urban concept created with the "three magnets" theory, based on the outcomes of human relations, green areas and the town [23,24]. Howard contributed a new more sustainable urban model in the early 20th century.

The American architect Frank Lloyd Wright in 1954 created a new organic philosophy of architecture in his book "The Natural House" and is considered a pioneer of green architecture [25]. These principles were developed based on the relationship with nature and the quest for indoor comfort in harmony with nature and the environment. Wright's construction model is recognised as the concept of bioclimatic architecture.

The healing effect of being in contact with nature was defined by Ulrich in 1984 [26] in the recovery of patients in rooms overlooking natural environments.

In 1984, Edward Wilson developed the concept of biophilia and, together with Stephan Kellert, enunciated the biophilia hypothesis [27]: our natural tendency towards biophilic life is the very essence of humanity and connects us with all other species, as has subsequently been confirmed by numerous researchers [28]. However earlier, in 1972, Erich Fromm previously used the term biophilia to describe a passion for all living things, as a biologically normal instinct [29].

The WHO (World Health Organization) in its Ottawa Charter in 1986 [30] at the First International Conference on Health Promotion based its strategy on the creation of healthy environments. These are areas where natural spaces such as gardens, parks and urban

forests can function as therapy and health prevention by facilitating contact with nature, social relations and exercise.

According to Kaplan's 1989 theory of attention restoration [31], mental fatigue caused by daily activities can be restored in contact with the natural environment. Furthermore, in agreement with Ulrich's 1991 stress reduction theory [32], contact with green areas produces a restorative effect by generating positive emotions, thus managing the emotions and stress transmitted by urban environments [33,34].

Today, after a busy day, relaxed listening to the sounds of nature can improve psychological recovery by up to 37% [35].

Recovering the balance with nature by integrating it into the spaces where people live was the aim of Ralph Rapson in 1945 [36] when he created his Greenbelt House project, the predecessor of biophilic design, which considered nature as an active part of the space.

However, in the bibliography, Stephen Kellert is recognised as the pioneer of biophilic design; in 1995, he integrated nature into construction, seeking to satisfy human needs and providing an enriching multi-sensory environment in both direct and indirect experience. He identified more than 70 ways to generate a biophilic experience [37]. Some authors named the architect Yeang as a predecessor of biophilic building [38].

In 2012, the company Terrapin Bright Green [39] published its report entitled "The economics of biophilia" highlighting the value of biophilic design for people's well-being and the construction of healthy environments. Two years later, in 2014, Terrapin Bright Green developed 14 patterns of biophilic design to improve health and well-being in the built environment [40], based on previous studies. Its aim is to guide and advise on the biophilic design of buildings in order to incorporate the natural world into the built environment based on experience. The patterns help to identify a space and create a relationship with its natural surroundings, seeking a visual and non-visual connection with nature, sensory stimuli associated with nature and thermal variations. The presence of water is a key aspect, along with dynamic light, the reference to forms present in nature and the incorporation of natural materials available in the local environment. Also important are an open and pleasant panoramic view and a place of refuge from daily activities.

In this line, Timothy Beatley created a framework of biophilic cities and, in 2016, published the "Handbook of Biophilic City Planning & Design" [41], oriented to biophilic urbanism, its adaptability and resilient results.

The European Green Capital Award was created in 2010 as an initiative of 15 European cities to recognise the good work of cities that adopt healthier and more sustainable lifestyles. The slogan of the award is "green cities: open to life" [42]. A network of biophilic cities has also been created, which includes a series of resources related to nature in cities, the influence of COVID-19, and changes and advances in biophilic urban planning [43].

Nikos A. Salingaros developed the Biophilic Index B to predict the positive health effects of a building [44]. Ten factors can be used to estimate the biophilic impact on emotional and physiological health, although this index cannot determine the weight of each factor. This biophilic index could be useful for building renovation. Another instrument created by Berto and Barbiero, the Biophilic Quality Index [45], helps architects integrate nature in design and promote restorative environments.

Biophilic urbanism is also evolving towards regenerative actions in public spaces or abandoned buildings [46,47].

Figure 2, created by the authors, shows the evolution of biophilic design from its earliest beginnings.

3.2.c. How does the evolution of biophilia in building justify its study?

The current perception, which has been accelerated by the COVID-19 pandemic in relation to public-health-related difficulties, highlights the importance of the sustainability of our planet for our own well-being. Thus, health and sustainability need common approaches. This will mean rethinking the entire urban system in the coming years, in order to face major challenges such as the demographic transition with the ageing population and the epidemiological transition together with the growth of large cities, environmental

pollution and climate change. Biophilic design, which is barely three decades old since it was started by its pioneer Stephen Kellert, is slowly taking off, driven by the current concerns of architects, urban planners and international organisations. It may be the answer to the need for a healthy human habitat, integrated with nature and recovering the link with the natural environment. Green infrastructure must be part of a healthy human habitat. Investing in nature can therefore improve our health and our cities.



Figure 2. The timeline of the evolution of biophilic design.

3.3. Finalise the Research Question to Reflect the Timeframe, in Two Questions

3.3.a. How can the scope of the research change the initial research question?

The studies show how the design of spaces influences people's lives. Biophilic design conceives the space as somewhere where people live and work in contact with nature, integrating the natural world in an attractive and pleasant way and generating positive emotions.

Encouraging healthy lifestyles at all stages of life by improving healthy environments will have a direct impact on people's lives. In addition, outdoor activities in contact with nature encourage ecological behaviour [48], so that people safeguard nature and nature protects our health.

3.3.b. How does the information sought actually answer the question?

A range of tools and systems show the potential benefits of biophilic environments, although more factors of biophilic quality are studied than measurable indicators [49]. A major gap in the bibliography is the need for an approach to consider the interconnecting factors that affect human health.

3.4. Develop a Search Strategy to Find Relevant Manuscripts

The methodology has been applied as an iterative process to approach the study area, in two questions:

3.4.a. How far am I from knowing the current situation of the target of the study?

In the current post-COVID-19 era, new methodologies are emerging that look at biophilic design from a holistic perspective for environmental health, sustainability and wellness living [50].

3.4.b. Do the sources of information help to answer the question posed?

Biophilic design is becoming increasingly highly valued [51]. There is a need for buildings that are integrated with nature [52]. New research reinforces the idea of the positive impact of biophilic design on people's health and well-being, a concept that is currently evolving and developing [28]. However, there is still very little literature on biophilic design and its impact on health. More indices such as the Salingaros Index [44], which estimates the biophilic impact on emotional and physiological health, are needed to understand in detail which biophilic factors influence people's overall well-being and to quantify the impact of each factor on the health benefits.

3.5. Analyses in Eight Phases (See Table 3)

3.5.a. Main articles consulted in the references mentioned in this manuscript and included at the end of the article.

The main techniques applied in the bibliography are case studies (22%) and literature reviews (20%). Qualitative studies represent the majority methodology (56%), while quantitative studies are less commonly used (14%). Surveys are the most common methodology in the primary studies. Table 4 shows a summary of the methodology analysed in the bibliography.

Table 4. The methodology applied in the bibliography analysed.

Methodology	%	Research
Semi-structured interview	1%	Qualitative
Focus groups	2%	Qualitative
Scenarios	2%	Qualitative
Observation	4%	Qualitative
Statistical methods	4%	Quantitative
Neurosciences	4%	Qualitative and quantitative
Reflexivity	5%	Qualitative
Surveys	10%	Quantitative
Secondary studies	10%	Qualitative and quantitative
Experiences and experiments	16%	Qualitative and quantitative
Literature reviews	20%	Qualitative
Case studies	22%	Qualitative

3.5.b. Common points

The various sources cite many elements as common characteristics of a biophilic space, including natural lighting, views of nature, vegetation in the spaces and the incorporation of natural materials and water. Rooms with views, spaces with indoor plants and green walls generate high levels of creativity and can reduce stress. Places that offer a view of landscaped areas therefore have a positive impact on the value of the space. Natural light and airy environments induce well-being and motivation.

Biophilic design is based on three fundamental aspects that can be applied at the city, building and room level:

1. Nature in space: natural elements of the space.
2. Natural analogies: designs inspired by nature.
3. Nature in the environment: the spatial configuration of nature, open spaces.

3.5.c. Assumptions

The scientific publications that have appeared over the last forty years show the importance of the connection to nature in our daily lives [53].

Biophilic design can help reduce stress, improve cognitive functions, increase creativity and productivity and contribute to well-being and recovery. People seek better

environmental quality, and biophilia is an essential component in contributing to good environmental, air, water and soil quality and to health and well-being.

Direct contact with natural vegetation has a stronger physiological impact than the incorporation of artificial vegetation [54]. The use of natural materials such as wood creates a link with nature.

Nature is changeable, so incorporating the natural environment into the design will avoid the impact of inactivity, resulting in more pleasant and dynamic spaces.

According to the Department of Public Health at Harvard University [55], a healthy building is characterised by the following:

- Guaranteed air quality, free of pollutants and with a humidity level between 30 and 60%.
- Water quality and a good water purification system.
- Thermal comfort.
- Natural lighting, the use of energy-saving light bulbs.
- Decoration inspired by nature.
- Insulation of rooms from noise pollution and humidity.
- Building security.
- Proper cleaning to protect rooms from dust, dirt and pests.
- The use of noble materials such as wood, cork and stone.

A recent study shows that natural green decoration on building fronts also increases citizens' well-being [56].

3.5.d. Main gaps

Patterns of biophilic design are evolving as new studies and research are incorporated.

While there is a large body of literature on the impact of green infrastructure on human well-being, blue zones such as lakes, rivers, lagoons and coastal zones have been less studied. This also affects biophilic designs.

For a good integration of a building in the natural environment, an in-depth study must be carried out of the local climate, flora and fauna.

Sustainability involves recovering this management of natural conditioning factors so that the biophysical matrix once again becomes the preferred source of local resources for building, taking into account the use of space and individuals' behaviour.

3.5.e. Contradictions

For some researchers, nature's influence on people is nothing more than a statement of an innate affinity that has been known for centuries.

3.5.f. Applications

According to a study by Oliver Hearth [57] and other works consulted in this research, the benefits of biophilic design in the construction of each space are as follows:

- ❖ **Offices:** Creativity increases, productivity increases by 8%, well-being values increase by 13%, and absenteeism due to illness is reduced by 1.6% each year. There is evidence of correspondence between biophilic office design and employee health [58]. According to the Human Spaces report [59], workers in offices with natural elements report a 15% higher level of well-being, are 6% more productive and are 15% more creative. This is achieved through natural lighting, landscaped areas, outdoor views, the use of natural materials and outdoor spaces. According to a 2018 study by CBRE for healthy offices [60], offices with biophilic walls and indoor plants make 76% of employees feel more energised, 78% happier and 65% healthier.
- ❖ **Hotels:** Guests would pay 23% more for a room with a biophilic view. In the post-COVID-19 era, tourists perceive the benefits of nature and show a preference for biophilic design attributes in their accommodations [61].
- ❖ **Schools:** Natural spaces improve concentration and attention levels, reduce ADHD (attention deficit hyperactivity disorder) and increase student learning by 20–25%.
- ❖ **Hospitals:** With natural areas nearby, the use of analgesics is reduced by 22%. In addition, indoor plants can reduce stress and increase pain tolerance [51]. The positive impact of biophilic design patterns in healthcare spaces has been studied, showing that direct experience of nature is more effective than simulated natural analogues [62].

- ❖ Shopping: Integrating nature into new urban areas makes retail spaces more attractive [63]. Shoppers in shops on green streets could spend 25% more and would pay between 8% and 12% more for products and services. If shops have natural lighting, sales could increase by 40% more.
- ❖ Housing: Green spaces contribute to an area's tranquillity by lowering crime rates by 8%. House values could rise by 4% to 5%, with some sources estimating this figure to be as high as 20%. In addition, homebuyers would pay 7% more for homes with excellent landscaping, 58% more for those facing water and 127% more for those facing the sea.

The benefits of the design may be different depending on the final green construction options [64].

3.5.g. Current reference models

The need for international standards to guide and recognise biophilic reference designs has led to the creation of two international reference standards: the WELL Building Standard [65] and the Living Building Challenge [66]. Both standards aim to promote the well-being and health of people in the built environment.

- The WELL Building Standard integrates natural patterns inside and outside a building with an appropriate narrative. The WELL certification links building knowledge with research into people's health in a perfect marriage focused on holistic well-being. The aspects considered by the WELL label are as follows: indoor air quality, water quality, distribution and control, fruit and vegetable growing areas for healthy eating, optimal lighting for good health, the promotion of physical activity, thermal comfort and personalised climate control. In addition, the WELL standard seeks the acoustic comfort of its inhabitants and their cognitive and emotional well-being and the restriction of toxic and hazardous materials; it promotes healthy spaces that favour the social interaction of the community.
- The Living Building Challenge is the father of living building, incorporating nature into the environmental characteristics of construction. It promotes sustainable building standards with the least impact on the surrounding natural ecosystems, with special attention to the energy efficiency of buildings and the natural materials used, and facilitates healthy lifestyles.

A concept associated with sustainable building is the TOD standard (Transit-Oriented Development) [67] for sustainable cities, which aims to create safe, balanced and vibrant cities. The eight basic principles of TOD design are walkable neighbourhoods, favouring non-motorised transport, connecting street networks, high-quality public transport, mixed land uses, optimising public transport diversity and capacity, compact regions with short trips and increasing mobility with the use of regulated parking.

Recently, in 2022, nine groups of experts brought together by the organisations CGATE (Consejo General de la Arquitectura Técnica de España), GBCe (Green Building Council Spain) and AEICE (Clúster de Hábitat Eficiente) carried out work to contribute their vision of what a healthy building should be. In Chapter 9 of the book "Buildings and health" [68], reinventing the habitat with people's health in mind, they state the following:

"The environment affects people's brains, emotions and cognitive capacities.... In cities, issues such as safety, accessibility and the proliferation of green spaces help to encourage healthy habits in the population... Everything related to the built environment also affects physical health and well-being. Ensuring thermal comfort, ergonomics, water quality and enjoyment of sunshine and views impacts on both quality of life and life expectancy".

Biophilic design is explicitly mentioned in hospital construction.

The Green Building Council Spain (GBCe) has published the first assessment guide, GREEN Buildings 2022, which includes the Connecting with Nature indicators [69]:

- Biophilia-enhancing landscaping.
- Visual contact with plant elements.
- Nature in the building.

- Dog-friendly spaces.

In 2023, Madrid Salud published a guide to performance, housing, home and health [70], incorporating biophilic indoor design with its benefits and recommendations.

3.5.h. Future research lines

As we become more aware of the importance of biophilic design for people’s health and the positive impact of these spaces, the perception of space is changing towards a construction that goes beyond energy efficiency and domotics towards healthy environments integrated with living nature. The data provided by the different studies agree on the benefits they offer, although the quantification of the figures varies considerably from one report to another. Rigorous studies are needed to be able to objectively assess the improvements in productivity and welfare offered by biophilic designs. Reliable indicators should be designed for the construction and renovation of buildings with healthy criteria. Biophilia is multi-scale and offers a wide variety of solutions; tools will be needed to calculate the real return on investment. We need to improve built spaces by knowing the local natural environments, identifying the negative aspects that affect our overall health and creating new designs that integrate them into the natural environment and bring us well-being.

Table 5 shows a summary of the analyses with the relevant aspects created by the authors.

3.6. Interpretation of the Results

While sustainable buildings in the early 2000s were primarily focused on energy efficiency, today the concept has evolved to include people’s well-being and the creation of healthy buildings. In recent years there has been a trend in architecture and public health to improve living spaces [18,71].

The COVID-19 pandemic has generated considerable interest in healthy biophilic spaces, suggesting a growing awareness of the need to live in spaces that are in contact with nature. Nevertheless, some studies have identified weaknesses and threats, such as biophobia, including negative emotions towards nature, feelings of boredom, socio-political influences and increased costs [17,72].

The design of healthy buildings includes comfort, energy efficiency and environmental impact; aesthetics and health are also part of the design process. They therefore seek to improve indoor air quality, thermal comfort, natural and artificial lighting adjusted to circadian rhythms, noise damping, natural views and biophilic design.

It should be noted that the lack of indicators for quantifying the direct and indirect benefits of these spaces makes it difficult to demonstrate their outcomes. However, it has been possible to identify the main factors of a healthy biophilic space, and it is also possible to evaluate the quantitative impact of several biophilic factors on people’s well-being.

This current situation presents an opportunity to integrate and coordinate preventive and therapeutic health efforts in the building field with all the stakeholders involved.

Table 5. Summary of the analyses.

3.5.a. Main articles consulted	in the references
3.5.b. Common points	Biophilic design is based on three fundamental aspects: 1. Nature in space: natural elements of space. 2. Natural analogies: designs inspired by nature. 3. Nature in the environment: the spatial configuration of nature, open spaces.
3.5.c. Assumptions	Biophilic design can help reduce stress, improve cognitive functions, increase creativity and productivity and contribute to well-being and recovery.
3.5.d. Main gaps	A good integration of the building in the natural environment requires the following: An in-depth study of the local climate, flora and fauna. A biophysical matrix for the use of space and individuals’ behaviour.

Table 5. Cont.

3.5.e. Contradictions	Nature's influence on people is nothing more than a statement of an innate affinity that has been known for centuries.
3.5.f. Applications and benefits	Offices ▲8% productivity ▲13% well-being ▼1.6% yearly absenteeism due to illness >15% creative with natural elements 76% of employees feel + energies 78% happier and 65% healthier
	Hotels Would pay + 23% more with biophilic view
	Schools ▲concentration ▼ADHD (attention deficit hyperactivity disorder) ▲20% learning
	HOSPITALS ▼22% use of analgesics with natural areas nearby
	SHOPPING - Integrating nature makes retail more attractive +25% could spend more on green streets +8% pay more for products and services ▲40% sales in shops with natural light
3.5.g. Current reference models	HOUSING ▼8% crime with green spaces ▲4% house values 58% more value for areas near water 127% more for areas near the sea
	WELL Building Standard Living Building Challenge GREEN Buildings 2022 by GBCe
3.5.h. Future research lines	The design of reliable indicators for the construction and renovation of biophilic buildings with healthy criteria.

4. Discussion

This research study confirms that the biophilic design of spaces for people's well-being is currently in a state of evolution. There are few rigorous scientific investigations, the experiences carried out are limited and partial, there are hardly any reference bibliographies and authors and the current reference models are only now beginning to be applied.

Several studies focus on the numerous benefits, from improved thermal performance to greater pro-environmental behaviour [17,72]. However, the lack of a quantitative evidence-based approach is today a major obstacle [73]. Architects and urban designers have been intuitively exploring the potential for restorative effects [74]. Biophilic design is still at the stage of perceptions, sensations and preferences [28].

The SotA methodology applied based on reflexivity could bring critical thinking to benefit biophilic design and open up future lines of research on this topic. Using the SotA method compared to other literature analyses such as systematic and scoping allows us to analyse the evolution timeline of biophilic design and identify the common aspects and main gaps. SotA offers a broad overview of the problem, contributes to an understanding of the topic with different approaches to the problem and supports claims about the relevance of the topic by providing an overview of the research. The lack of homogeneous and consistent data can pose a challenge for conducting a meta-analysis in this area. Although

a methodology based on data description could be used with Open Research Knowledge Graph (ORKG), the insufficient structured academic knowledge generated on this research topic makes this inviable [75].

The SotA method has some limitations due to its subjective analysis process and the lack of validation of the literature. However, reflexivity helps identify and interpret the appropriate literature [14,15]. SotA is a recently developed methodology and probably needs more applications. The limitations of these studies must be considered when selecting the search criteria and analysing the databases. Research conducted with different criteria on other databases or even on the same one can therefore give different results [76].

The following are recommendations for future lines of research:

- ❖ More interdisciplinary research is needed; the great challenge is to explore new solutions inspired and integrated by natural models for healthy building development.
- ❖ Applying new technologies such as neuroscience, the Internet of Things, virtual reality and augmented reality.
- ❖ Testing current experiences and validating results in different applications (hospitals, residences, schools, shopping centres, etc.) with homogeneous and clear criteria.
- ❖ More contrasting scientific data and empirical experiences could support a quantitative and qualitative meta-analysis.
- ❖ Finally, the development of a standard biophilic taxonomy for application at different levels and sectors could support the sharing of knowledge and create a common vocabulary for future studies.

5. Conclusions

The COVID-19 pandemic has brought a more realistic vision of what our cities should be, with an emphasis on well-being and healthier and more sustainable living.

Biophilic design is incorporated into the concept of sustainable and healthy new construction and housing renovation, which is the way of life in the near future.

The study examines the applications of biophilic design and its potential benefits, such as reducing stress, improving cognitive function, increasing creativity and productivity and contributing to well-being and recovery.

There are as yet scarce data and very few studies that evaluate the quantitative impact of biophilic design on well-being. The previous research is more of a scientific discussion of the hypothetical and intuitive effects.

Further research will be needed to measure the positive effects of implementing biophilic design using multidimensional expertise in a cost-effective way. This will contribute to monitoring and understanding the progress of healthy spaces for people.

New lines for future studies are needed to provide real evidence of the effects of biophilic design on holistic well-being and quality of life. One recommendation for transparent and verifiable evidence would be to develop a standard biophilic design taxonomy by levels and sectors and a unique common vocabulary.

Finally, this study compiles the current relevant bibliography and sources in the SotA biophilic design and innovation methodology, suitable for exploring emerging new topics.

After COVID-19, the biophilic design of healthy and sustainable spaces has only just begun.

Author Contributions: Conceptualisation, N.B.-A.; methodology, N.B.-A.; validation, E.A.-T.; formal analysis, N.B.-A.; investigation, N.B.-A.; resources, E.A.-T.; writing—original draft preparation, N.B.-A.; writing—review and editing, N.B.-A.; supervision, E.A.-T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

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