

*Review*

## **A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design**

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**Abstract:** Biophilic design has received increasing attention as a design philosophy in recent years. This review paper focused on the three Biophilic design categories as proposed by Stephen Kellert and Elizabeth Calabrese in “The Practice of Biophilic Design”. Psychological, peer reviewed literature supporting the benefits of Biophilic design was searched for through the lens of restorative environments. Results indicate that there exists much evidence supporting certain attributes of Biophilic design (such as the presence of natural elements), while empirical evidence for other attributes (such as the use of natural materials or processes) is lacking. The review concludes with a call for more research on restorative environments and Biophilic design.

**Keywords:** biophilic design; restorative environments; built environment; environmental psychology

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### **1. Introduction**

Biophilic design is a design philosophy that encourages the use of natural systems and processes in the design of the built environment [1]. Biophilic design is based on the Biophilia hypothesis, which proposes that humans have an innate connection with the natural world [2] and that exposure to the natural world is therefore important for human wellbeing. However, human interaction with nature is often lacking in modern day societies [3] due to societal trends such as urbanization, building design, and

lifestyle. The idea behind Biophilic design then is to incorporate natural features and systems into the built environment in order to provide human beings with their much-needed exposure to nature [1].

Biophilic design has received increasing interest from the building industry around the world in recent years. Two building rating systems that originated in the United States but are being promoted globally incorporate Biophilic design directly; these are the Living Building Challenge [4], which incorporates it through the Biophilia Imperative, and the new WELL Building Standard [5], which incorporates it through the Biophilia Precondition and Biophilia Optimization. Consulting firms have also championed the concept, notably Terrapin Bright Green, who have published various white papers on Biophilic design [6] and Interface flooring, who have created a Human Spaces website [7] to encourage discussion around Biophilic design.

This paper will review evidence for Biophilic design and will focus on environmental psychology literature, which has a long tradition in examining the potential healing benefits of exposure to nature and natural elements as proposed by environmental restoration theory. The paper also discusses differences in the way individuals respond to nature. The paper will argue that there is a need for more evidence to demonstrate how the different elements of Biophilic design affect different people.

## 2. What is Biophilic Design?

Biophilic design encourages the use of natural elements and processes as design inspiration in the built environment [1]. The idea behind this is that exposure to natural environments and features have positive effects on human health and wellbeing, which has been supported in a wealth of research [8]. According to the Biophilia hypothesis, these positive effects of exposure to nature originate in a biological bond between humans and the natural world [2]. These ideas have been taken forward in two theories developed in the Environmental Psychology literature: Attention Restoration Theory [9] and Stress Recovery Theory [10]. Both theories suggest that some environments are stressful, others are not and yet others can actively help people recover from stress and mental fatigue. Environments that evoke positive moods, have properties that draw people's attention without being stressful or demanding, can help people recover more quickly and fully from mental fatigue and stress are known as restorative environments [11]. According to Kaplan and Kaplan [9] and Ulrich and colleagues [12] natural environments in particular contain elements that promote renewed attention by providing a sense of being away, fascination, extent and compatibility [13]; and by containing elements that promote survival and therefore positive appraisal [14]. Urban environments, on the other hand, tend to be full of demanding, stressful, under stimulating or boring features.

Biophilic design then suggests that built environments could be made more restorative by incorporating natural elements in their design. Gifford and McGunn [11] suggest that Biophilic design can be viewed as belonging under a larger restorative design umbrella. Much of the small but growing peer-reviewed literature on Biophilic design often cites research on restorative environments to support the health and wellbeing benefits of Biophilic design [15–17]. Although the concept of Biophilic design is relatively new, the plethora of research on nature and restorative environments makes a strong case for the health and wellbeing potential of incorporating Biophilic design attributes into the built environment. However, this research does not always test all aspects of Biophilic design and although there is

significant evidence for the beneficial effects of exposure to natural environments, evidence for other Biophilic aspects, such as the use of natural materials, is sparse.

The evolution of Biophilic design characteristics has led to the recently published document “The Practice of Biophilic Design” by Stephen Kellert and Elizabeth Calabrese [18]. The document details the three experiences and 24 attributes of Biophilic design, and is an update on previous literature on Biophilic design [1,3]. The three experiences and 24 attributes are listed in Table 1.

Evidence from over three decades of research on the impact of nature on human health and wellbeing can justify the claim that Biophilic design is beneficial, although academic literature looking specifically at Biophilic design is still relatively rare. One of the first academic papers on Biophilic design came from Joye [17] who looked at empirical research from various fields of psychology and how it applied to Biophilic design. Joye [17] concluded that existing research, mostly in the field of restorative environments, lends support to the ideas of Biophilic design. The review [17] did not look for specific literature on Biophilic design attributes [1], as this review does. Likewise, in a chapter on restorative environmental design by Hartig and colleagues [19] restorative environments were looked at as a basis for Biophilic design, but the chapter does not review specific Biophilic design attributes; instead support for Biophilic design was focused on general support from restorative environmental design research. Several years have passed since these reviews were conducted, and the evidence in support of Biophilic design has increased. The current paper attempts to evaluate the evidence for each of the three experiences distinguished by Kellert and Calabrese [18] to support the theory that Biophilic design is beneficial for psychological wellbeing.

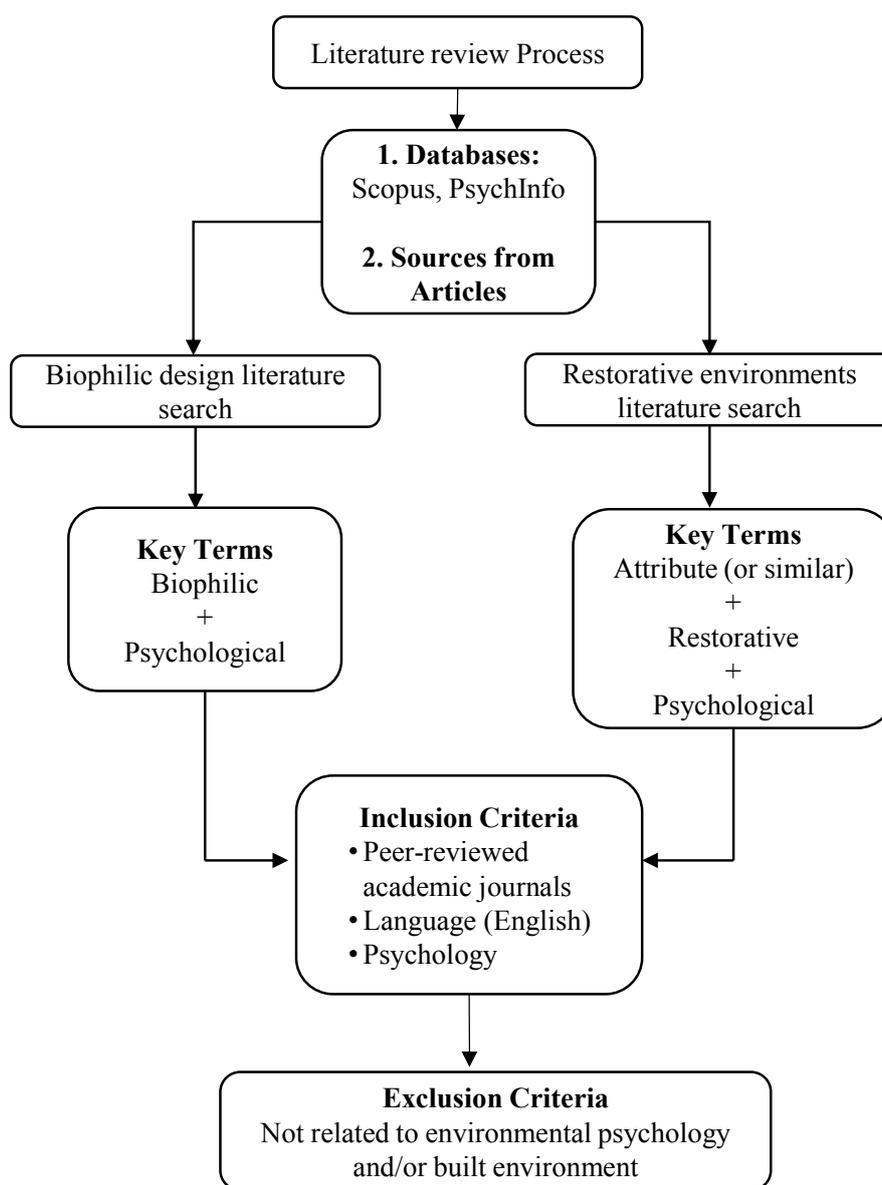
**Table 1.** Experiences and attributes of Biophilic design by Kellert and Calabrese [18].

<b>Direct Experience of Nature</b>	<b>Indirect Experience of Nature</b>	<b>Experience of Space and Place</b>
Light	Images of Nature	Prospect and refuge
Air	Natural materials	Organized complexity
Water	Natural colours	Integration of parts to wholes
Plants	Simulating natural light and air	Transitional spaces
Animals	Naturalistic shapes and forms	Mobility and wayfinding
Weather	Evoking nature	Cultural and ecological attachment to place
Natural landscapes and ecosystems	Information richness	-
Fire	Age, change and the patina of time	-
-	Natural geometries	-
-	Biomimicry	-

### 3. Method

The review provides a specific environmental psychology perspective on Biophilic design. Environmental psychology focuses on studying interactions between people and their physical (natural and built) environment and therefore is particularly useful for understanding Biophilic design. The literature review examines literature on people’s perceptions and attitudes towards the natural and built environment (with reference to Biophilia) as well as their behaviours, feelings and experiences in such environments. As such the review will draw on two important theories in environmental psychology

literature: Attention Restoration Theory (ART) [9,13] and Stress Recovery Theory (SRT) [12] to examine the evidence for positive experiences in environments with natural elements. Scopus and PsychInfo were used to search for peer-reviewed, academic literature in the field of psychology. The review searched for evidence of positive effects of each of the three Biophilic experiences on a range of psychological outcomes such as improved cognitive functioning, reduced stress, and improved mood, which all contribute to improved health and wellbeing. Figure 1 details the search methodology for this narrative review. A vast amount of psychological literature was looked at for this review, which gives an overview of some of the key findings. It is not meant to be exhaustive but to provide an insight into the quality and quantity of evidence for each of the three Biophilic experiences as found in psychological literature.



**Figure 1.** Narrative review process.

#### 4. Results

The following section details the results of the psychological literature search on the three Biophilic design experiences. Some overlap exists between the independent variables (the 24 attributes) explored

in research and this was mentioned in the overlapping attributes. For example, water will be seen as being highly restorative in the built environment from both direct and indirect nature experience. Moreover, different natural elements often feature together in environmental design, making it difficult to distinguish clearly between different aspects of Biophilic design.

#### *4.1. Direct Experience of Nature*

The direct experience of nature experience and its relevant attributes yielded the most peer-reviewed research for this paper. The direct experience of nature means having a direct contact with nature and natural processes [18]. The eight Biophilic design attributes that are used in this experience are listed in Table 1. The most researched attributes in this experience category in psychological literature are the use of plants in the built environment and natural landscapes and ecosystems. Additionally, research from a restorative environments perspective was also found on natural day, light, water and weather. Literature exists on the wellbeing benefits of the other attributes but inclusion of them was outside the restorative environments focus of this review paper.

##### 4.1.1. Natural Light

Natural light has been promoted by various disciplines as being beneficial for wellness of building occupants, including psychology [20]. However, in the research for this paper few results were found that studied restorative environment research along with natural light. This may be due to the fact that a psychological theory on the benefits of natural light has yet to be described [21] although Beute and de Kort found that daylight was associated with perceived restorative potential [22]. Most of the research on the benefits of natural light is approached through a biological explanation, such as circadian rhythms and vitamin D production [21]. From a Biophilic view, humans evolved under natural, diurnal light conditions and therefore natural light and natural light processes should be preferred and most beneficial. From research on restorative environments, Zadeh and colleagues looked at the restorative potential of natural light and windows [23]. This quasi-experiment found that the availability of natural light and windows significantly improved mood and communication amongst nurses. Although the use of windows and natural light may be confounding, a study on children in a classroom in Sweden [20], found that children in rooms with daylight fluorescent lighting without windows had improved concentration when compared when compared with children in classrooms with no windows and conventional lighting. This study also lends support to the simulating natural light and air attribute in the indirect experience of nature category. Daylight spectrum lighting that changes throughout the day to mimic natural light, such as circadian lighting, could be a way to better reap the benefits of natural light.

##### 4.1.2. Water

Water has also been found to be restorative, both through views of water [12] and sounds of water [24]. Kaplan and Kaplan [9] note how preferred environments often have a view of water and this was also found in various other studies [25–27]. In fact, images of the urban environment that contained water were found to be even more preferred than nature images containing no water [26]. As with views to nature, the quality of water impacts the restorativeness, meaning that brown, dirty water will be less

restorative than clean water [26]. Incorporating clean water elements into the built environment has also been suggested by Ryan and colleagues [15] as a way to tap into the Biophilic benefits of water. Articles that have focused on the psychological benefits of water have noted that there is much research on the physiological benefits of water, however less so on the psychological wellbeing benefits. As part of the results of a systematic, meta-analysis conducted by Volker and Kistemann in 2011 [27], water was found to be restorative.

#### 4.1.3. Plants

Plants have the ability to directly bring green, living nature into the indoor environment. Psychological studies have demonstrated the health and wellbeing benefits of placing plants inside. Bringslimark and colleagues [28] conducted a review of this evidence and concluded that plants have a beneficial effect on stress reduction and pain tolerance. In an earlier study, Larsen and colleagues [29] found that as the density of plants increased in an office setting, productivity decreased. At the same time, positive affect increased. This is in contrast to a more recent study by Nieuwenhuis and colleagues [30] who found that perceived and actual productivity increased for occupants in a green (including plants) office space when compared with a lean (minimalist) office space.

Although much research has been conducted on the health and wellbeing benefits of plants, little research has been done on the qualities of plants that humans prefer. In a study by Qin *et al.* [31], various plant types were tested to identify the most beneficial type of plant based on psychological and physiological assessment. The results indicate that small, green, lightly scented plants were the most optimal for health and wellbeing. Plants with red flowers were found to be fatiguing after a period of time [31]. This could be explained by research on colour and creativity, where red has been found to be beneficial on tasks that require concentrated attention [32].

#### 4.1.4. Weather

Academic literature on the role weather plays on psychological restoration is limited; however, there is some evidence supporting this attribute. In terms of this attribute in relation to the interior environment, the argument made by Kellert and Calabrese [18] is that there is importance for building occupants to maintain a connection to the exterior world, including its natural processes. People have been found to prefer sunnier weather and that this weather also is rated higher in terms of perceived restorativeness potential [22]. This lends support to the psychological restoration potential of the type daylight, depending on the levels of sunshine. Translating this to the built environment further supports the psychological benefits of natural light, while at the same time considering the quality of natural light that people are exposed to while indoors.

#### 4.1.5. Natural Landscapes and Ecosystems

The view of greenery from a window, which is listed under the natural landscapes and ecosystems attribute, has been shown in several studies as having beneficial effects on the wellbeing of building occupants. A major study by Ulrich [33] was on the benefits of green views when recovering from gallbladder surgery. Patients who were recovering in a room with views to green trees recovered faster

and required less pain medication than patients whose view was of a brick wall. This is a good indication that in the built environment context, the type of view does matter. The type of view was also found to be of importance in a study by Felsten [34]. More in depth-results of this paper will be discussed in the images of nature attribute. However, Felsten found that a mundane view of nature during the late Fall was less restorative than a simulated view of nature containing water and more dramatic nature [34]. This study again points to the significance of understanding the restorative potential of a natural view, especially in climates and seasons where lush, green nature is unavailable.

In areas where an urban environment is the limiting factor towards viewing green nature, the availability of green roofs have been found to be restorative. The extent of restorative potential depends on the type of vegetation, with a popularly used vegetation type, sedum, being viewed as not being significantly more restorative than non-vegetated roofs [35]. The authors note that the sedums used on the pitched, residential roof were not green but rather reddish, which may have affected the appraisal of the roof [35]. In a recent study of the micro-restorative potential of flat green roofs, white flowering, green roofs were found to provide a micro-restorative effect on attention after only 40 s of viewing the roof [36]. The authors of this study noted that they compared a white flowering flat green roof with a barren grey roof; whether the largest effect of the roof was due to the greenness or white flower aspect remains to be studied.

#### *4.2. Indirect Experience of Nature*

The second experience proposed by Kellert and Calabrese [18] is the indirect experience of nature. This experience is important, as direct contact with nature may not be possible in every design situation, such as in certain medical environments, and looks at representation of nature in the built environment. This experience has ten attributes, which can be found in Table 1.

##### *4.2.1. Images of Nature*

The use of images of nature in the built environment has been widely investigated in environmental psychology. Images of nature have been found to be as stress reducing as actual views of nature in certain circumstances [37]. Building occupants' need for human interaction with nature is so strong that office workers have been found to compensate for a lack of nature exposure by adding images of nature to the office environment [38]. By incorporating permanent Biophilic features into the built environment, designers can ensure that everyone reaps the benefits with contact to nature, and not just occupants that feel comfortable with personalizing their space, or those who have the ability to do so. In an environment where direct exposure may not be possible, such as a sterile medical environment, images of nature can provide a connection to the natural world for both patients and medical professionals.

Images of nature can even be more restorative than the view of real nature, depending on the content of the image and the view of nature. Using Attention Restoration Theory (ART) as a framework, Felsten [34] asked students to imagine they were mentally fatigued and to rate various images on their perceived restorative potential. Felsten [34] found that students perceived mural views of nature with water as the most restorative, even more than actual views of nature through a window of what Felsten calls "mundane nature" [34], meaning that the trees were devoid of leaves, since it was late Autumn.

Therefore, images of nature may have a large role in environments where exterior views with lush nature may not be possible, due to seasons, adjacent buildings, or external environment.

#### 4.2.2. Natural Materials

Natural materials are another Biophilic attribute that falls into this experience but this attribute has received limited attention in academic research from a psychological perspective. The limited research demonstrates that the amount and type of material is important for perceived restorative quality and preference. Nyrud and colleagues [39] manipulated images of a patient hospital room with different quantities and layouts of wood, using wood that was commonly used in the Norwegian building industry, which was the location of the study. The amount of wood in a patient room that was most preferred was an intermediate amount, with the floor, one wall and furniture being made of wood. An entire wood surfaced room and a room with no wood were the least preferred amongst respondents [39]. Although the respondents had the same overall preference, there were differences, with physicians providing overall higher ratings for the images than nurses [40]. The results of this study again demonstrate that the amount and type of Biophilic feature, as well as the target audience, needs to be considered in design. In terms of other research on natural materials, for this paper wood was the only material found that was related to Biophilic design research. This provides an opportunity to investigate other materials, such as natural stone, various clays, strawbale, hemp and other types of wood. Materials that are indigenous to a building location could also be further investigated.

#### 4.2.3. Natural Geometries

This attribute primarily deals with fractals, although also includes other natural geometries such as the Fibonacci sequence as well [18]. The study of fractals offers an explanation as to why humans are restored by nature. Fractals occur when a pattern repeats itself as it gets smaller or larger, what Joye [17] refers to as “self-similarity”. Kellert [1] notes that some notable historical buildings contain fractals, which includes Gothic architecture, notably cathedrals [17]. Fractals have been found in many natural elements, for example the Romanesco broccoli. This could be an explanation as to why natural environments are often preferred over built ones [40] or why fractals have been used in historical architecture.

### 4.3. Experience of Space and Place

The third and final experience, the experience of space and place, relates to the spatial elements of the natural environment and how to replicate it into the built environment [18]. There are six attributes in this experience, which are listed in Table 1. Based on the review of psychological literature on restorative environments, three attributes will be discussed.

#### 4.3.1. Prospect and Refuge

There has been work done on prospect refuge theory, however not in relation to restorative environments [41–43]. One study on prospect and refuge in relation to restorative environments was found for this paper [44]. The study was done in the natural world and did not use the built environment, much like many of the previously cited studies related to restorative environments. Nature that is

non-threatening is thought to be restorative and this can be applied to the built environment context as well. Results from this study demonstrated that nature with high levels of views and low levels of prospect were deemed restorative; nature with low level of views and high levels of prospect were not. Although being in nature may have the potential of being more threatening than a controlled environment in a building, the authors attribute the results in part to wayfinding, which has been studied in the built environment context. Wayfinding is the ease at which a person can manipulate an environment. When a person has problems finding their way, their levels of stress rise [45].

#### 4.3.2. Cultural and Ecological Attachment to Place

Another attribute proposed by Kellert and Calabrese [18] in this experience is cultural and ecological attachment to place. Place attachment is an area of research in environmental psychology that “refers to the sense of rootedness people feel toward certain places, a phenomenon sometimes called a sense of place” [45]. The work that is relevant here is work on favourite places, which have been associated with place attachment and restoration. But this work is conducted by only a handful of authors namely Korpela [46,47] and Hartig [47]. Places that are perceived to be highly restorative have been found to have strong place attachments for people [48]. In relation to this, in a 10-month longitudinal study, natural environments, most likely due to their ability to afford restoration, have been found have a stronger attachment as a favourite place [46]. An application of this with regards to Biophilic design or built environments that incorporate nature was not found for this paper. Although the literature on favourite places suggests that there is a link between place attachment and restoration this is highly subjective and an experience that develops over time and perhaps not something that is simple to design.

It must also be noted that restorative environments do not need to be natural, which agrees with Gifford and McGunn’s statement [11] that Biophilic design falls under a larger umbrella of restorative design, and not necessarily vice versa. In a purely restorative environments context, Ouellette, Kaplan and Kaplan [49] looked at a monastery as a restorative environment using ART as a framework and found that the monastery served as a restorative experience. Through self-reports of the study’s participants, the environment was noted as being restorative due to the soft fascinating elements of the architecture, in agreement with ART. This could be applied to other environments as well, such as the home. This does not take away from the benefits of Biophilic design. Literature, as identified in this paper, on the benefits of incorporating nature in the built environment would suggest that while other environments can be restorative, incorporating Biophilic attributes in to these same environments might only increase the restorative potential of the environment.

### 5. Individual Differences

Individuals may respond differently to Biophilic elements, which need to be considered in Biophilic design. Van den Berg and ter Heijne [50] found that male individuals and those that are higher sensation seeker respond more positively to threatening encounters in nature than females and those that are lower sensation seeker. Also found by Van den Berg and ter Heijne [50] was that any type of nature could yield fear. This can be translated into the built environment, notably with environments that have high prospect but cause some people who are fearful of heights to become stressed. Another individual difference is that not everyone actually likes nature [51] and that this should be considered in design. In

this study, Bixler and Floyd also note that this may be due to people being used to a building environment, where the environment is relatively controlled [51]. Biophilic design may increase the likeability of nature by more exposure to natural processes and elements in a controlled environment. This can increase a person's connection to nature [52] and may encourage them to engage more in wilderness nature.

Individual differences in the built environment context have also yielded significant results. In a study by Kweon and colleagues [53], images of abstract and nature art produced significant decrease in anger and stress in male office workers, but not female. The abstract art used in the study was Biophilic in nature, which was noted by the authors as explaining the results, since previous research had indicated that abstract art was distracting [53]. Differences between genders in restorative environments were also found by Shibata and Suzuki [54], where females demonstrated improved performance when plants were incorporated into the room when compared with males. In both studies, context is important, where the type of task [54] and environment may play a large role in the different outcomes by gender. This can be used by designers when considering Biophilic design by understanding the type of task and stressors that people will experience in their environment.

## 6. Current Trends in Biophilic Design

Although much research on restorative environments has focused on the visual sense, recent research in the field of restorative environments has yielded a shift from the visual sense to the auditory sense and olfactory senses. This shift supports Kellert and Calabrese's statement that the experience of nature is multisensory [18]. Referring back to the study by Qin and colleagues [31] on the use of plants, the type of plants that were most highly rated as restorative were those that were slightly fragrant. Additionally, the sound of bird song [55] and nature sounds including water has been perceived to be highly restorative [24].

Part of the complexity of Biophilic design is that although much research has been done on the individual elements of Biophilic design (e.g., Plants, images of nature, and natural light) the combinations of elements has received little attention in research. The first longitudinal study on a Biophilic-designed space that incorporates various elements of Biophilic design is currently underway in Australia [16]. The study looks at natural light, plants, natural ventilation, prospect and views, use of non-synthetic materials, recycled materials, and an open-plan workspace. The space that is being studied is a work-site construction office and the first paper of the two-year study was published using three months of data. The preliminary results after three months indicate that the various benefits of Biophilic design are being realized in the space. This includes reduced stress, improved productivity, and improved wellbeing, which all fall under the benefits of being in a restorative environment as well.

As stated by Kellert [1], Biophilic design works with low-impact environmental design to create buildings that are what he calls restorative environmental design, which are not to be confused with restorative environments which is a focus in this paper. With the current focus on green building design, Biophilic design attributes have an opportunity to enhance green building design strategies. Biophilic design is incorporated into the Living Building Challenge [4] which is perhaps the most progressive green building rating system on the market, and in order for a building to achieve "Living" certification, it must meet the requirements for each of the 20 imperatives, including Imperative 09 Biophilic Environments. Imperative 09 requires that the design team look at the six Biophilic elements as proposed

by Kellert [1] and demonstrate how they have been incorporated into the design. Beyond this imperative, the Living Building Challenge (LBC) also has other imperatives that touch upon Biophilic attributes, such as Imperative 07, Civilized Environment, which promotes fresh air and natural light for building occupants (Attributes 1 and 2; see Table 1) Imperative 16, Universal Access of Nature and Place and Imperative 19, Beauty and Spirit. Imperative 16 ensures projects do not impede upon natural light, fresh air, or disturb natural waterways on adjacent developments and people (Attributes 1, 2 and 3; see Table 1), while Imperative 19 ensures that projects integrate elements that are pleasing for people, which could include cultural and spiritual celebration (Attribute 24; see Table 1).

The WELL Building Standard is a brand new rating system that was launched in 2014 and focuses on the human health and wellbeing in the built environment [5]. This standard includes two areas that are dedicated to Biophilic design, one compulsory and the other optional, with the compulsory area being modelled after the LBC Imperative 09, Biophilia. Other areas in the system exist that tap into Biophilic design as well, such as areas that focus on providing outdoor air, on-site food production, daylight and circadian lighting, as well as the potential for other areas as well. This is a positive step towards integrating more Biophilic design principles in the built environment.

In another recent publication on Biophilic design, Terrapin Bright Green synthesize the concepts put forth by Kellert [1], Cramer and Browning [56] and others and propose 14 patterns of Biophilic design in order to help aide designers in creating Biophilic space [15]. This is a good start and opportunity for designers who are looking for design advice to go when searching for Biophilic design strategies.

Biophilic design does not need to follow a rating system in order to be successful. The most important aspect of Biophilic design is tapping into the innate connection humans have with the natural world and ensuring that people feel this connection while inside. Historical evidence supporting this design philosophy dates back millennia [57]; well before the establishment of a rating system and even current buildings may have Biophilic design properties without being labelled as such. The benefit of incorporating Biophilic design into a rating system is that rating systems have the ability to shift the conversation in the building industry. This has been seen in recent years with green building rating systems, such as the Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Methodology (BREEAM) rating systems [58]. As it stands right now, WELL is extremely new and already much talked about, collaborating with the United States and Canada Green Building Councils [59] and the LBC is only growing in uptake, with eight projects having achieved “Living” certification since its inception in 2006. By identifying rating systems that directly use Biophilic design in them, the point of this section is only to inform of industry uptake in Biophilic design directly; this does not mean that this is the only way to achieve a Biophilic space.

## 7. Conclusions

A review of Biophilic design from a restorative environment perspective yielded many results demonstrating the benefits of Biophilic design for human wellbeing. It is acknowledged that the review is by no means exhaustive and some of the attributes that have been proposed by Kellert [1] may have been studied in areas of literature, inside and outside of psychology, and are not included in this paper. However, the majority of work on Biophilic design refers to environmental restoration theory as an underlying basis. As such this review focused on psychological literature examining the evidence for the

restorative qualities of being Biophilic attributes, or the extent to which the presence of such elements in a built environment can help foster recovery of stress and mental fatigue. Empirical evidence supports the use of plants, water, wood, *etc.*, in creating spaces that provide an opportunity for human wellbeing. Three additional points need to be made in response to this review:

### *7.1. Biophilic Design is not a One Size Fits all Approach*

Like many design philosophies, Biophilic design strategies need to be employed in consideration with the building occupants, location, and function. There may be a threshold for the amount of plants and the type of plants that will be beneficial for certain human activity. For productivity, a room with too many plants may decrease productivity while improving affect [29]. A room with many red plants may be psychologically draining on the occupants or can be beneficial for short-term concentrated attention [31]. Restoration does not need to happen at all times; it is situational and contextual, meaning that the needs for a Biophilic home surrounded by green nature will be different from those of a Biophilic office in a central, extremely densely developed urban environment. Sometimes nature and replications of nature is not restorative and therefore stressful for humans [44], and when applying Biophilic principles into the built environment, this needs to be considered. Finally, some environments can be restorative that are not necessarily filled with plants [49].

Individual differences between building occupants also need to be considered. Men and women react differently to images of nature, with men showing a marked decrease in anger [53]. Further individual differences may also play a role but have not been studied much.

### *7.2. Suggested Areas for Further Research in Restorative Environments*

Although nature is multisensory, the vast amount of research on restorative environments depends on the visual aspects of nature. This is changing as research is looking at other senses with regards to restorative potential, however for this review, much of the literature found depended on the visual sense. The Biophilia hypothesis would suggest that much of nature and its processes are beneficial for humans and therefore, restorative. This would include natural light, natural and indigenous materials, *etc.* and all the human senses. However academic work for certain attributes, such as natural light and natural materials, and their link to restoration was limited. As called for in other works cited in this review, more research is needed in other areas of restorative environments, which is currently dominated by greenery.

### *7.3. Suggested Areas for Further Research on Biophilic Design*

There is a need for a systematic review of the literature perhaps broadening it out to a wide range of literature in psychology, health, planning, architecture and engineering. There is also a need to understand more about the specific contribution of different design features not only in terms of wellbeing—as was the focus of this review—but also in terms of sustainability, and to better understand how different factors work together to achieve positive outcomes and optimize building design.

While individual attributes of Biophilic design have been studied on their own, there has been little research on the various combinations of proposed attributes. Do plants and natural materials have a larger impact than plants and water? Does natural light have a larger impact on attention than plants?

How is research on natural light and concentration in school children coincided with ART and SRT? There are so many exciting areas of future research on this topic and that of restorative environments, which will yield a greater understanding of the mechanisms and potential for design based on a Biophilic design philosophy.

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### Author Contributions

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### Conflicts of Interest

The authors declare no conflict of interest.

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