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Loving Nature From the Inside Out: A Biophilia Matrix Identification Strategy for Designers

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Abstract

Objective: The development of the Biophilic Design Matrix (BDM) was to aid designers or other specialists in identifying and quantifying biophilic features through a visual inventory of interior spaces. **Background:** With mounting evidence to support the healing attributes of biophilic environments, we propose a method to identify biophilic content within interior spaces. Such a strategy offers much promise to the advancement of restorative environments. **Methods:** The BDM was based on Stephen Kellert's biophilic design attribute list and modified to be appropriate for interior environments, specifically children's healthcare spaces. A photo-ethnographic documentation method of 24 child life play spaces within a South Atlantic state was used to determine whether the BDM could reliably reveal biophilic features (listed as attributes by Kellert in 2008). **Results:** This matrix appears useful in documenting biophilia within the pediatric healthcare context, attesting to the usability and functionality of the BDM for this special population. Specifically, the BDM revealed that biophilic attributes were constantly present in some spaces while others were completely absent. When a biophilic attribute was present, the BDM indicated that they varied considerably in type and occurrence. Thus, use of the BDM in the hospital areas designed for patient recreation and play successfully provided a visual inventory of biophilic features as well as the frequency of application. **Conclusions:** Further use of the BDM as a tool for strategizing biophilic feature inclusion can thus increase the connections available with nature in the interior, beneficial for optimizing health and wellness.

Keywords

biophilia, Biophilic Design Matrix, child life, interior design, restorative environmental design

Biophilia Identified

Despite growing interest in biophilia across allied design fields, interior designers and architects are still challenged by the identification and application of biophilic features in the interior built environment. Three decades after Edward O. Wilson (1984) hypothesized biophilia as an innate human need to affiliate with nature—thereby benefiting

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from natural conditions that positively impact physical, spiritual, social, and psychological well-being—the design community continues to explore and seek application of this biophilic thinking (Hartig et al., 2011; Kahn, 1997; S. Kaplan, 1995; Louv, 2008; Matteson, 2013; Salingaros & Masden II, 2008). Associated benefits of human–nature connections offer protection from the adverse impacts of daily living and allow for personal restoration while supporting holistic living within the earth's systems (Hartig, Bringslimark, & Patil, 2008). In this light, Stephen Kellert (2008) proposed restorative environmental design (RED) to include both low impact, sustainable building practices and biophilia that collectively enhance the human–nature relationship.

Assuming RED, people would be expected to nurture nature for planetary health and, in turn, nature may nurture people for optimized health. Thus, together biophilia and low-impact design could form a cyclical support system for the long-term benefit of both the people and the planet. Although rating systems such as the Leadership in Energy and Environmental Design (LEED; U.S. Green Building Council, 2010) have increased research on low-impact building (Denzer & Hedges, 2011; Driza & Park, 2013), integrating biophilia explicitly into the interior is still ill defined. To do so, one first has to be able to identify what might be described as biophilic.

The Biophilic Design Matrix (BDM) assists designers and other experts of the built environment with biophilic identification and is the subject of this article. By using the BDM instrument, designers can begin to use biophilia as a type of filter for making design decisions and the early use of this instrument in the design process may foster designers' awareness of the innate reasoning behind many of their design decisions. Further, by bringing the innate to conscious awareness, designers who include natural features in interiors may come to rely upon research-based design solutions while simultaneously elucidating the need for additional research. To illustrate, consider that direct contact with "wild nature" (features not requiring human intervention) has been found to have the most powerful health effects, especially regarding use of daylighting, which has been shown through research to either directly or indirectly to decrease stress, increase job satisfaction, reduce depression, and aid circadian rhythms (Joseph, 2006).

Despite growing recognition of the positive effects of natural conditions, Americans are routinely separated from the natural environment now more than any time in history with an average of approximately 93% of life spent inside (Klepeis et al., 2001; U.S. Environmental Protection Agency & Office of Air and Radiation, 1989). Importantly, architects and particularly interior designers are positioned to reconnect people with nature through the interior environment. Thoughtfully designed biophilic spaces can provide people with a restorative connection to nature that benefits health and wellness, including reducing stress (Hartig et al., 2008). This practice of biophilic design could also lead to an environmental awareness of humanity's interconnection to nature and the need for long-term optimization of the earth's resources.

People–Nature Interconnection: The Environment and Humanity

Current separation from the out-of-doors has created a need for research strategies that use biophilic design features indoors to impart the most beneficial influence. The need for such research can be especially beneficial for pediatric as well as for caregivers who are sequestered inside all day and often are not able to go outdoors for direct contact with nature. Although the interior environment is positioned to host the integration of biophilia well, the presence of biophilic features has been somewhat abstract and illusive to designers in application. As a tool for designers, the BDM was developed specifically to identify and quantify the variety of biophilic features present in pediatric play spaces, which is the focus of this investigation.

This research was an extension of previous work showing a health connection between the people and the natural world through restorative environments (Derr & Kellert, 2013; Hartig et al., 2008; Kellert, 2008). Human health requires nature supplying necessary resources, the most obvious being water, air, light, food, and materials for shelter. These are a few of the items we need from nature but there are other ways of looking

at the human–nature relationship. One particular aspect of integrating low-impact design and biophilia together is the goal of preserving natural resources as well as fostering connections with nature for an end game that restores natural ecosystems for the future. True sustainability then becomes both a hedonistic and an altruistic outcome. Both low-impact design and biophilia then need to be supported in the built environment toward a goal of a sustainable future, but also in regard to research showing possible immediate benefits such as positive impacts on health.

RED and Humanity: Biophilia and Health

Research tying specific health and wellness influences to biophilia began with the work of Roger Ulrich (1984) and his consideration of the effects of the physical environment on patients' recovery from gallbladder surgery. He found patients with a view of a tree healed faster, required fewer pain medications, and had fewer negative charted notes from nurses than those patients who had views only of a brick wall. Surprisingly, even though direct contact with nature did not occur, health benefits still seemed to be related to this type of passive biophilic experience. This study was especially important to those involved in the design of the built environment, particularly healthcare spaces, because Ulrich's now classic study was also the foundation of evidence-based design. The goal of evidence-based design is to use credible research to guide design decisions for the best possible outcomes (Center for Health Design, 2010). The direct health-related benefits of nature and its interaction in the built environment showed that not only can research be a part of the design process but it should be fundamental to design decisions, especially regarding health, safety, and welfare. Moreover, the findings from Ulrich's (1984) influential study positioned biophilia as perhaps more important to both designers and researchers than originally known.

More recent examples of research, such as investigating biophilic features in support of healthful influences, have continued to expand the body of knowledge. One study revealed that sunlight had a positive effect on job satisfaction and the general well-being of employees (Leather, Pyrgas, Beale, & Lawrence, 1998). The same study revealed that employees with views of natural features including trees, vegetation, and plants experienced less negative job stress and had greater employment longevity. Clearly, findings such as these point to the potential effects of natural conditions—even passive conditions—to benefit economic, psychological, and physical health through day-to-day interactions in the interior environment. Additional research continues to reveal the link between natural conditions and the healthful influences nature can have on people (Derr & Kellert, 2013; Hartig et al., 2011; Kellert & Heerwagen, 2008; Wells & Evans, 2003).

Through combining biophilia with low-impact building design, Kellert (2008) envisioned a healthier planet and healthier people. Low-impact design alone is not truly sustainable if future generations demolish efficient buildings and send the refuse to landfills. Although existing buildings and new low-impact buildings may have low energy consumption as a key measure of sustainability, additional considerations also should be made (Carroon & Moe, 2010). The goal of RED is to combine the preservation of long lasting and positively impactful buildings with interior and exterior biophilic features. These features can support the optimal health and wellness of the occupants by providing a connection to nature. Thus, the biophilic connection extends the sustainability mind-set to seek restoration of nature and to a built environment that lives in harmony with nature.

Fortunately advances in low-impact environmental design have increased through use of the U.S. Green Building Council's rating system LEED (Kellert, 2008; U.S. Green Building Council, 2010). The LEED checklist of sustainable features uses total earned points to determine a level of certification for the building (U.S. Green Building Council, n.d.). The effectiveness of this tool has promoted the goal of sustainability regarding awareness, innovation, and implementation of green building techniques and strategies. It has the greatest number of points focused on energy efficiency and has become widely used. LEED, however, has its shortfalls. For example, LEED emphasizes energy efficiency over other building

attributes and the prescriptive requirements for assessments have resulted in differences in the proposed versus actual impacts (Denzer & Hedges, 2011; Driza & Park, 2013). Nonetheless, LEED with its credit/no credit scoring has enabled green building to gain a foothold.

In a similar vein as LEED, the Living Building Challenge is now growing to be a robust tool that advances sustainable design with a restorative approach that seeks to produce a net positive output, including energy, but also including food and other resources (International Living Future Institute, 2014). The goal of the challenge is "in the words of Buckminster Fuller—To make the world work for 100% of humanity in the shortest possible time through spontaneous cooperation without ecological offense or the disadvantage of anyone" (International Living Future Institute, 2014). This approach goes beyond attempts at minimizing environmental impact but to restoration, or regeneration as the challenge defines it, of nature. The Living Building Challenge requires a preliminary audit similar in approach to LEED where many of the imperatives ("credits" in LEED) are reviewed for compliance before the building is occupied. The challenge also includes a 1-year occupancy performance evaluation for other imperatives at which time the final audit will determine if the building is certified as a Living Building. Requirements include a selection among 20 imperatives, including one named biophilic environment. This biophilia inspired imperative is aimed at fostering human–nature connections through a biophilic plan, which is arrived at through a day-long exploration of how the project will customize a strategy to incorporate biophilic concepts. The problem with this approach has been a lack of structure and data to support its further development (Green & American Society of Landscape Architects, 2012).

A tool that assists and documents biophilic elements will not only assist designers' development of healthful interior environments that include natural features and conditions, but also support design research necessary to designers' understanding of biophilia and its effects on well-being. The hypothesis in this investigation was that a tool utilizing LEED's system of credit/no credit scoring may support designers' awareness and integration of biophilic elements and attributes while also providing a means by which designers could use biophilia as a filter for decision making in their design process.

Biophilia and Humanity: Biophilia in Daily Living

Edward O. Wilson's hypothesis that biophilia is the "innate tendency to focus on life and lifelike processes" (1984, p. 1) created the groundwork that began to explain existing and new research findings with important and perhaps unexpected implications and applications. The variety of research around biophilia that has emerged makes clear a case for interaction with nature, including beneficial effects that can occur in the interior environment.

The word "biophilia" comes from *bio* or life and *philia* a platonic love, from the original Greek (Orr, 1993). Wilson's (1984) view was of a biophilia based on the Greek love *eros*, eliciting selfish devotion similar to the way that the term conservation is viewed as a selfish biological intent. This view of biophilia has been modified (Kahn, 1997) by considering the Greek love *agape* (selfless love) as a type of morality (Kellert, 1997; Orr, 1993)—a condition occurring through learned experiences beginning in childhood in nature (Katcher & Wilkins, 1993; Simaika & Samways, 2009; van den Born, Lenders, Groot, & Huijsman, 2001). This does not mean that any accompanying fear of nature (biophobia) is viewed through rose-colored glasses, but rather that our attraction to aspects of nature can provide positive health benefits and that our aversion of dangerous factors, like snakes, is also beneficial in keeping us safe from harm.

Learned rules, as hypothesized by Wilson (1984), are a weak biological tendency requiring complex sensory stimuli that interacting with nature provides. Biophilia develops when sensory stimulation and contact with nature are inherent in the cultural context. Kahn (1997) conducted extensive research of structural-developmental theory to advance biophilia through looking at experience, learning, and culture by interviewing children across multiple cultures. Kahn found that a consistent connection with nature was more

universal and that culture may only play a small part in biophilia but that nature is important to children's development. If such connections are not fostered, a nature-deficit disorder may result (Louv, 2008). Although not a medical ailment, nature-deficit shows physical and psychological consequences to being in the modern built environment. Since hospitalized children are often sequestered indoors due to isolation precautions and are not allowed outside despite their desire (Committee on Infectious Diseases and Committee on Hospital Care, 1998), this kind of separation also may lead to nature-deficit disorder and requires additional research.

Rachel Kaplan and Stephen Kaplan (1989) explored a different source of the human–nature connection by considering their theory of directed-attention fatigue, which distinguishes between directed attention (focused concentration) and fascination (likened to creative daydreaming). Voluntary or effortful directed attention is essential to understanding the world around us, but our attention can become depleted through prolonged use (S. Kaplan, 1995). Yet people were both calmed and able to overcome mental fatigue while experiencing nature in a daydreaming state. Memory performance and attention spans were improved with even an hour of nature interaction (Berman, Jonides, & Kaplan, 2008), while urban settings required more directed attention. Natural settings allow for indirect or soft fascination to occur, which provides a higher quality restoration (Herzog, Black, Fountaine, & Knotts, 1997). The research path of directed attention led to Attention Restoration Theory (S. Kaplan, 1995).

Proposed by Stephen Kaplan in 1995, Attention Restoration Theory is an integrative framework where directed attention and stress are considered as they interact with each other in the context of the human–environment relationship. Attention Restoration Theory looks at four areas. First, it explains how attention fatigue can result from information processing and can lead to stress. Second, it considers that people can enjoy something while still being exhausted by it. Third, fatigue and stress can be experienced differently, and fourth, people can feel stressful about situations differently depending on fatigue. Thus, "attention is the key ingredient in human effectiveness, both independently as well as in relation to other cognitive functions" (Berto, 2005, p. 258).

Nature is a key coping mechanism for psychologically and physically dealing with challenges while also improving cognitive functioning (Berman et al., 2008). An example is found in Ulrich and colleagues research (1991) with 120 subjects who viewed a stressful movie and then experienced a video that showed either natural or urban settings. Decreased blood pressure and more complete physiological recovery occurred with the natural setting experience. The ramifications of this are important to design application. Specifically, children are especially vulnerable to environmental influences; Derr and Kellert (2013) found that children can receive from nature "developmental benefits, such as increased attention capacities, cognitive function, social and creative play, and improved motor skills. At the same time, they are most vulnerable to the risks associated with a degraded planet or toxic environments" (p. 31). These studies offer a sampling of how researchers have begun to uncover nature's influences on people.

Biophilic Identification in Interiors: The BDM

Kellert's Initial Operationalizing of Biophilic Design

If biophilia is an innate biological need that deepens through experience within the cultural setting or through independent exploration, then people should already be drawn to biophilic features and these features should be inside where people spend most of their time. The design challenge presented by biophilia is defining what are biophilic design features, how are they currently being integrated into space, and how they may be purposefully incorporated into the built environment. Further, the integration of low-impact design practice with biophilic design for restorative buildings needs more exploration of its benefits to human and environmental health. To start to address these issues, we begin with the identification of biophilic features. Some features such as daylighting, living plants, and animals may quickly come to mind as natural features that can

be included inside, but other qualities of the natural environment that enhance connections with nature may be included in the interior (Kellert, 2008). Kellert began to operationalize biophilia by identifying and categorizing 72 features of natural conditions in interior and exterior built environments. Kellert describes his list as a way for designers to pursue "the practical application of biophilic design in the built environment" (2008, p. 5). Although designing for biophilia is important for people generally, it is perhaps particularly so when designing for vulnerable populations such as children in healthcare environments.

Biophilic design: A strategy needed for application. Closer examination of Kellert's (2008) feature list shows the 72 nature-based design attributes fall under six elements within two overarching biophilic dimensions—all focus on the essence of natural properties or objectives. The *organic dimension* includes "shapes and forms in the built environment that *directly*, *indirectly*, or *symbolically* reflect the inherent human affinity for nature" (2008, p. 5). These three types of organic interactions include *direct* experience which occurs with natural features that do not need human sustainment such as daylight, animals, and native plantings, often called "wild nature." Second, *indirect* experience occurs with natural features that do require human involvement such as potted plants. Both direct and indirect experiences have been shown to be beneficial. Kuo and Taylor (2004) found that experiencing park and manicured lawn spaces had positive influences on children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD).

The third type of organic interaction is *symbolic* experience which has no direct contact with nature itself but occurs with representations such as images or movies. This last type is the least effective, as research generally reveals that direct interaction is the most influential. Kjellgren and Buhrkall (2010) found that both an outdoor environment and a simulated image of the outdoor space presented inside provided stress reduction, but the outdoor environment also increased participants' energy levels and fostered higher degrees of altered state of consciousness. Benefits of symbolic interaction have also been demonstrated in research such as Ulrich's (1981) study showing more positive influences on people's well-being by their simply viewing images of nature than viewing urban scenes. Importantly, each interaction whether direct, indirect, or symbolic had some degree of positive effect on human health and well-being.

The *organic dimension* includes the first four element categories. The first element is *environmental features*, which are the most obvious and well-recognized nature characteristics, and includes 12 attributes such as *water* and *animals*. The second element, *natural shapes and forms*, are representations and simulations of nature and includes 11 attributes such as *representing botanical motif and shapes resisting straight lines*. The third element is *natural patterns and processes* with properties derived from natural features and processes. Examples of the 14 attributes of this element include *central focal point* and *fractals.* The fourth element is light and space that considers light qualities and spatial relationships seen among 12 attributes such as *natural light* and *spatial variability.* A list of each element and attribute for this dimension is included in Tables 1–4.

The second overarching dimension, *place-based* is a connection to the local natural identity (e.g., geography). This rooted connection specific to the particular place is seen as the spirit of the place where the person and space react to form a unique connection (Steele, 1981). The connection that people have with buildings and spaces is somewhat intangible and spirit of place has many shades of meaning. It is often found in an emotional connection to historical events, unique qualities of a building, locality particulars, or cultural connections that bring the spaces themselves greater meaning (Brook, 2000). "However, we need to be alert to its metaphorical nature; it is a technique to help us along the way to experiencing place, not a description of the reality of any particular place" (p. 146). The uncovering of spirit of place requires one to be sensitive to the uniqueness of a place.

Apparent distinctiveness of place derives from an ability of people to see buildings as part of their personal and social identity and is important for motivating responsible stewardship (Kellert,

Table 1. Environmental Features—Most Obvious and Well-Recognized Nature Characteristics.

Color	Any type of color
Water	Any type of water
Air	Natural ventilation
Plants	Actual plants in any form (alive or previously alive)
Animals	Actual animals in any form (alive or previously alive)
Natural materials	Not artificially made and coming from the environment (e.g., wood, stone, metal, and paper)
Views and vistas	Exterior views of natural features such as vegetation
Fire	Fire providing comfort and civilization when controlled with color, warmth, and movement

Note. Attributes originally proposed by Kellert (2008), not included: sunlight, facade greening, geology and landscape, habitats, or ecosystems.

2008). The territoriality of "home" is an example as the construct home can be extended to other places (Bachelard, 1994). These are the spaces we defend and even love—they become eulogized spaces or topophilia. The meaning of topophilia is an "affective bond between people and place or setting" (Tuan, 1990, p. 4) and because people all experience place differently, it is the similarity among people that create a commonality definable as the spirit of place. The erosion of unique identity for a place is where everything looks and feels alike and encourages "placelessness" (Cresswell, 2004; Relph, 1976). This disconnect can lead to a lack of empathy for environmental stewardship. Consequently, facilitating such connections is important. These can be strengthened through features that connect the interior with the local environment, geography, history, ecology, culture, and through local materials and landscape. The use of these types of features in spaces can be key to fostering connections that ultimately aid long-lasting renewal of the built and natural environment. This element or category, *place-based*, is seen in the attribute named *place-based relationships*. It is culture together with ecology, rooted in the local geography and includes 11 attributes. Examples include *geographic connection to place* and *indigenous materials*. A description of this element and its attributes is included in Table 5.

The final element, *evolved human–nature relationships*, has paired biological needs in 12 attributes. It borrows from both organic- and place-based dimensions, as well as being a unique set of relationship pairings. It is the duality of each attribute that makes it unique. These attributes come from the human need for aspects in nature that "presumably reflect biologically based human affinities for the natural environment" (Kellert, 2008, p. 13). Including both components of the pairing in an environment provides a type of wholeness of experience that is based on biological nature experiences. *Prospect and refuge* plus *change and metamorphosis* are examples of the paired biological needs. This is further elaborated upon in Table 6.

The two overarching dimensions and specific features proposed allow for the inclusion of both the obvious features (e.g., live plants) and the less obvious features (e.g., bounded space) to be considered side by side. Although humans have long been incorporating these features in the built environment without a theory or research to support it, biophilia incorporates these various conditions while also providing a new rationale for the inclusion of each natural feature. Research that may exist around each individual feature may be analyzed further using this lens, as additional attributes are added or subtracted based on emerging biophilic research. Natural complexity and patterns are key components to the fascination eliciting value of experiencing nature (Salingaros & Masden II, 2008) and including a broad range of the features such as those listed by Kellert may help to build a complex nature connection. It also provides a starting place for analyzing interior spaces for biophilic features.

The BDM. Kellert's (2008) initial operationalizing of biophilic design features began with his proposed features list. This provided the foundation and inspiration for creating the BDM. The matrix facilitates documentation of biophilic design features in interior environments and is based on the descriptions of elements and attributes in natural environments presented by Kellert (2008). Not intended to provide "right or wrong answers," the

Table 2. Natural Shapes and Forms—Nature Representations and Simulations.

Botanical motifs	Representations found in shapes, forms and patterns of plants, and vegetative matter
Tree and columnar supports	Appearance or simulation of tree-like shapes, including rounded/columnar supports
Animal	Representations of animals (e.g., animal forms, claws, and heads) may be highly stylized
Shells and spirals	Invertebrate representations with the most common being shell and spiral forms, bees and their hives, flies, butterflies, insects, and spiders and their webs
Egg, oval, and tubular forms	Often used as design element details and seen in ornament and structural purposes such as columns, molding, and fountains
Arches, vaults, and domes	Copy of these forms found in nature for decorative or functional purposes including beehives, nests, shell forms, and cliffs, often found in decorative and functional purposes
Shapes resisting straight lines	Shapes such as sinuous, flowing, or adaptive to forces found in nature; nature features rarely are revealed as straight lines or right angles
Simulation of natural features and biomorphy	A simulation rather than replication of natural form; ornamentation or decoration of imagined forms are vaguely reminiscent of those naturally found
Geomorphology	Replicating or embracing nearby geology or landscaping next to the building in the interior
Biomimicry	A viewing of nature as a model; the imitation of functions found in nature can include the shapes of both animals and plants but focuses on function over replication of form

Note. Attributes originally proposed by Kellert (2008).

BDM instead provides a means to document existing biophilic features and their particular locations, thereby providing a quantitative attribute scoring protocol, as well as a visual inventory. The BDM may also foster insight into gaps or overlooked opportunities that might be reconsidered in a proposed design. New building planning can use the matrix to facilitate incorporation of a variety of biophilic features at the onset of the design process.

Research is lacking regarding a best or worst way to incorporate biophilic features but having access to such an instruments such as the BDM may advance design research for the health, safety, and welfare of users. The creation of the BDM instrument in 2011 was specifically designed for pediatric and adolescent play spaces. At the outset of the development of the BDM approaching biophilia quantitatively remained a challenge. Another biophilic instrument was developed to assess childcare centers (Caballero, 2013) with a narrow age range (34–38 months), which limited its generalizability while simultaneously signaling the need for such a tool.

Method

BDM: Design, Development, and Application

Development of the BDM instrument began with investigating Kellert's (2008) list of attributes and identifying biophilic features that could apply to interior space. Attributes best measured from the exterior of the building such as *sunlight* were not included in the BDM because of its focus on the interior. Sunlight is distinct from *natural light*, which is an interior feature, and was included in the BDM, while others were not included due to not being able to capture them through indirect observation. These qualities may be analyzed through interviews or behavioral mapping and could be pursued in future research. The matrix could be customized to include these features for other purposes. A partial sample of the matrix is shown in Table 7.

The BDM includes each of Kellert's (2008) element categories and their respective attributes that have been modified for clarity as well as their particular application in interior spaces. Scoring the BDM involved marking whether an attribute

Table 3. Natural Patterns and Processes—Properties Derived From Natural Features and Processes.

Sensory variability and information richness	The presence or variety of levels of visual complexity, light, sound, touch, smell, and/or other sensory environmental conditions, for a sensuous and intellectually challenging environment
Age, change, and the patina of time	Age showing such as in wear or growth particularly by organic forms like wood but even inorganics like stone, efflorescence
Central focal point	A singular point of reference or interest in a space
Patterned wholes	A variability united, variety becomes organized in a pattern (e.g., mosaic wall art)
Bounded spaces	As in a delineated space with clear boundaries, defined territories, and place demarcations
Transitional spaces	A space providing access between spaces, including hallways, bridges, and so on
Linked series and chains	Spaces connected that bring you from one space to another in a series
Integration of parts to wholes	Individual distinct components together create a greater whole (e.g., small wood planks can make up a wood floor)
Complementary contrasts	The blend of contrasting features or opposites, like light and dark, open and closed, and high and low
Dynamic balance and tension	Different or contrasting shapes, forms and materials may foster a sense of strength and durability, this blending of varying forces often produces a quality of creative tension that makes static forms appear organic
Fractals	Fractals appear similar from both near and far, implying that the degree of irregularity and /or fragmentation is identical at all scales, mathematically self-similar but not exact copies, like snowflakes and/or leaves of the same tree
Hierarchically organized ratios and scales	Ratios or scales arithmetically or geometrically based can be seen in naturally occurring patterns (e.g., golden ratio, golden sections, golden proportion, golden spiral, and Fibonacci's sequence (0, 1, 1, 2, 3, 5, 8, 13, 21, 34 . . .) such as the head of a sunflower and the petals of an artichoke, these can be highly complex patterns yet seem organized)

Note. Attributes originally proposed by Kellert (2008).

was present in the space or not. The BDM also provided space for photographic documentation of the particular attribute in situ. This process resulted in both a frequency count of attributes space by space and a visual inventory of existing biophilic attributes.

Visual images of the play spaces were captured using photoethnography, which describes the use of digital images to create a permanent record of inter- and multidisciplinary field conditions (Pink, 2013). Photography alone captures images but does not provide context for the details and features that are characteristic of the environment (Collier, 1986). Thus, an analysis of the photos in this study was guided by a set of directions for identification due to the site context, which included using only fixed or permanent features (i.e., not including small or temporary items). Also, it was limited to identification of items clearly visible. Together these two guidelines enabled for more dominant features to be recorded, which would be stable and obvious components to the pediatric users of the space.

Settings

The child life environments assessed in this study were 24 child life play spaces in the South Atlantic region of the United States. Certified Child Life Specialists (CCLS) are trained healthcare professionals who assist families through pediatric health issues and provide play and therapeutic interventions (Child Life Council & Committee on Hospital Care, 2006; Committee on Hospital Care and Child Life Council, 2014). Their play spaces are distinct entities in the healthcare environment specifically designed for children and adolescents. Design research has had a limited previous focus on child life play spaces.

Procedure

The initial development of the matrix began with focusing on trying to identify what existing features might be found. In order to control variables, child life play spaces were selected. Through

Table 4. Light and Space—Light Qualities and Space Relationships.

Natural light	Daylight/sunlight access inside
Filtered and diffused light	Modulated daylight to reduce glare (e.g., blinds and shades)
Light and shadow	Light and dark or shadowed spaces
Reflected light	Light reflecting off surfaces such as light colored walls, ceilings, and reflective bodies like water and shiny surfaces may provide sparkle
Light pools	Pools of connected light in a series (may include shadow) on the floor or wall drawing you from one area to another
Warm light	Warm lighting feels secure and inviting; the warm glow, sunlight, or fire is often surrounded by areas of darker spaces
Light as shape and form	Natural light manipulated to create aesthetic form (e.g., light shaft)
Spaciousness	Openness or large open space is often complemented with sheltered areas surrounding it
Spatial variability	Changes of light, mass and scale such as ceiling heights, room widths, and so on for visual variety in the definition of the space (hopefully balanced with unity to create spatial harmony, see spatial harmony)
Space as shape and form	Space that is manipulated into form or shape
Spatial harmony	Harmony in a space is often seen in a unifying commonality among the varied light, mass, and scale within a well-defined boundary
Inside–outside spaces	Interior spaces that appear connected to the outside environment, like porches foyers and interior gardens

Note. Attributes originally proposed by Kellert (2008).

Table 5. Place-Based Relationships—Culture Together With Ecology, Rooted in the Local Geography.

Geographic connection to place	Connection of the space to the geography of the site offers familiarity (e.g., use of local features, siting of the room, selection of views, etc.)
Historic connection to place	Relation to the past through the marking of the passage of time; linking the past to the present, fostering a culture's collective memory (e.g., historical images)
Ecological connection to place	Connection to local, dominant ecological, and biogeographical features of the region (e.g., mountains, deserts, rivers, and oceans)
Cultural connection to place	Integrated history, geography, and ecology of an area (e.g., architectural heritage of a people, particularly its treasured and distinctive vernacular/local forms)
Indigenous materials	Local or native materials
Landscape orientation and landscape features that define building form	The siting of the interior for bio-meteorological conditions like sunlight, wind direction, water drainage, and so on for integrating the building with the environment/landscape that embellishes or defines the building or interior design and connects the interior to the exterior (e.g., Falling Water)

Note. Attributes originally proposed by Kellert (2008), not included: landscape ecology, integration of culture and ecology, spirit of place, or avoiding placelessness.

institutional review board and child life managers, 24 of the 26 spaces in a South Atlantic American state agreed to allow for photo documentation of their child life play rooms. The digital images of each room were used to complete the BDM. Inter-rater reliability of 89% and 94% indicated that the BDM could be used to assess biophilic attributes in interior spaces.

Table 6. (Evolved) Human–Nature Relationships—Paired Biological Needs.

Prospect and refuge	A place with the ability to survey the distance/a view of the entire space with a place of protection/ separated from spaciousness
Order and complexity	A balance of structured organization with intricacy of detail that together appears orderly, designs that meld order with complexity stimulate the desire for variety in a controlled manner
Curiosity and enticement	Spaces that elicit exploration, discovery, creativity, or mystery
Change and metamorphosis	Present in growth, maturation, and metamorphosis and seen when one form or state changes to another

Note. Attributes originally proposed by Kellert (2008), not included: security and protection, mastery and control, affection and attachment, attraction and beauty, exploration and discovery, information and cognition, fear and awe, reverence, or spirituality.

Results

The process of using the BDM instrument provided both a quantitative accounting and a visual inventory of the various attributes present in the child life play spaces. The highest BDM score, 39 of a possible 52 points, was one of the larger spaces evaluated in the study and had a beach theme with a large aquarium. As seen in Figure 1, this space also had a sand castle play structure, many small interactive toys, access to an exterior play space, and a teen area. Two unique biophilic attributes it included were *water* and *animals* due to the presence of the aquarium.

Collectively, the child life spaces had an average total score of 21.5 attributes out of a possible 52 points or 41% ($SD = 6.45$). The average attributes score in the play rooms among the six element categories was 3.67. This score is in comparison to a total of 8.67.

Although these scores may seem low, use of the BDM revealed that spaces consistently included several of the biophilic element categories. The two most frequently occurring attributes were color and bounded spaces. Color is always present and has been studied thoroughly over time using various theories and approaches; however, its strategic use in an interior when gleaned from a naturally occurring condition of a particular environmental place deserves further study. Bounded spaces also are ubiquitous in interior spaces and purposeful in preventing movement, harm, or trespass into restricted or private areas. Bounds as extensions of natural conditions into interior space deserve further study.

Less ubiquitous, albeit frequently occurring attributes, were *egg, oval,* and *tubular forms* that were most often apparent in tubular items like steel chairs and table legs, and *natural materials*, which were most often scored for their presence in furniture, cabinetry, and trim. *Change* and *metamorphosis* described as being present in growth, maturation, and metamorphosis can be seen when one form or state changes to another. It was not found in any of the spaces. Also absent was *warm light* and *fire*, as well as *hierarchically organized ratios* and *scales.* Four attributes appearing only one time were *animals, biomimicry, cultural connection to place,* and *indigenous materials*.

The presence of separate teen spaces in five of the eight hospitals for a total of seven rooms was also a surprise. There was a difference in the score totals for the teen rooms compared to the rest of the play spaces. The teen room average BDM score was 18.29 out of 52 ($SD = 2.43$) compared to the BDM average of 22.82 ($SD = 7.15$) for the remaining 17 play spaces.

Implications for Practice

Helping Designers to Love Nature

The compelling body of research supporting biophilic integration into the built environment demands more attention be paid to evidence-based designing, specifically with biophilic features in interior spaces. Beginning with the initial operationalizing of biophilia through Kellert's (2008) list of attributes, the BDM tool assists designers through an inventory for classifying interior biophilic features. It can be used to assess existing spaces in quantitative terms and can be used to assist in developing a proposed design. Going through the process of using the BDM aids designers in evaluating interior spaces through a

Table 7. An Example Section of the BDM, Identifies the Element (Category) and the Corresponding Attributes With Written and Visual Identifiers: An X in the Scale Column Indicating the Presence of an Attribute, a Description of Those Items to the Right, and a Photo.

Biophilic Design Attributes (Element Categories Divided Into Attributes With Descriptions)	Scale (Present = X)	Description of Fulfillment of Attribute	Photograph Example (Image of Feature(s) Identified as Containing Attribute)
Natural patterns and processes element			
Sensory variability/information richness: the presence or variety of levels of visual complexity, light, sound, touch, smell, and/or other sensory environmental conditions, for a sensuous and intellectually challenging environment	X	Example: Water sounds from aquarium and from chimes; variety of color, size and textures throughout main play structure	(Supporting image inserted here)
Central focal point: a singular point of reference or interest in a space		Not found	

Note. Additionally a description and photograph of the feature identified would be included. Attributes originally proposed by Kellert (2008).

Figure 1. Example of interior photography and several play spaces with coordinating BDM scores (e.g., BDM:37 indicates the presence of 37 out of 52 possible attributes. One point is achieved per attribute present). Photo arrangement based on order of site visits. Reproduced with permission by Beth McGee, photographer.

biophilic filter that reveals opportunities to incorporate biophilic design features in creative ways. This can result in biophilic-infused environments that not only support vulnerable populations but also may facilitate a full range of end users.

Further use of the matrix in Shanghai with international schools offers additional support for the BDM as a supportive research instrument (Hollyman, 2015). This investigation led to findings that include a "strong correlation with students' perceptions of nature ... and the possible relationship between places students perceived as 'peaceful' and their biophilic attributes" (Hollyman, 2015, p. 109) and went on to say that the BDM results "implied biophilic design could provide an effective framework through which to envision a more restorative indoor environment" (p. 109). The Shanghai study described along with this research supports the BDM as a helpful step toward understanding how, where, and what biophilic features are being used and prompting new research supporting specific inclusion strategies.

Nature identified. This research builds upon Wilson's (1984, 1993) biophilia hypothesis and Ulrich's research linking nature, the built environment, and human health outcomes (Ulrich, 1981, 1984; Ulrich et al., 2008). Also, S. Kaplan's (1995) Attention Restoration Theory framework and subsequent research (Berman et al., 2008; Berto, 2005; Herzog et al., 1997; Kahn, 1997) begins to show that the human–environment relationship can be influenced through exposure to nature with resulting health implications. Additional study is needed regarding if there is a defensible method to guide the development of biophilic environments in interior settings, however, the use of the BDM is aimed at making that path easier. The matrix may also support designers in their work of creating nature-based and not necessarily nature-themed environments. The environments tested in the matrix development showed a wide variety of nature inclusion with an overall average presence of biophilia that was higher than the teen-only spaces, which were also not as obviously themed. When investigating other spaces that are not as heavily nature themed as many of these spaces ended up being, these scores may be comparatively highly rated. Future research can be helpful in replicating and extending these findings to the larger healthcare building, outdoor play spaces, and looking at how other types of spaces for adults and children vary. This can also be built upon to show trends among the attributes and elements in the variety of features being used.[1]

The lowest level of element inclusion occurred in the element categories of place-based relationships and evolved human–nature relationship (which were relabeled human–nature relationship for brevity and lack of specific evolutionary evidence). These two categories describe the need to connect to the locality or sense of place and the need for human–nature relationship pairings. Their lack of incorporation may be due to designers not intuitively knowing how to implement these elements. The innate desire to include representations of animals, plants, or other similar representational images may be sociologically more apparent to humanity as a learned or an innate approach to incorporating nature. It seems to be a common design approach to use a nature theme with children's spaces, but the reduced variety of natural features identified in the teen spaces compared to the overall pediatric spaces may show that nature integration is more difficult to accomplish when less obvious use of nature or a theme is not desired, especially without a tool like the BDM. Nature was included in varied amounts throughout the spaces, but it may not as quickly come to mind the ability to incorporate some of the lesser present attributes, such as a connection to the geography or ecology. A lack of cultural focus or a lesser amount of innate draw to add these features may be why they were not commonly found; however, use of the matrix might aid designers in identifying these unique features for increasing integration.

Supporting the love. Connecting children's health outcomes through nature connections is a developing field of biophilic research (Derr & Kellert, 2013; Louv, 2011). Empowering children through difficult health events is child life's goal and through play they seek normalization (Child Life Council & Committee on Hospital Care, 2006). Child life play spaces help mitigate the adverse

effects of the hospital environment for pediatric patients and their playrooms can be further supported through ongoing design research and biophilic play spaces. The findings from the implementation of the matrix show that people are bringing nature into children's spaces and this points toward a knowledge that nature is necessary for proper child development. Designers creating spaces that are optimally biophilic may be able to aid children and adults with physical and mental restoration, as well as provide connections to nature that fosters awareness for the global need of restorative environmental actions. That end impact of environmental advocacy through a biophilic love for nature makes the process of aiding designers to think with a biophilic filter throughout the decision process a great goal for distribution and use of the BDM. Children's environments specifically can capture health benefits by optimizing the integration of nature. The current focus on interior play spaces came out of the desire to understand the unique needs of child life play spaces within the desire to identify the nature-based variety currently being used in interior children's spaces.

Although the initial operationalizing of the biophilic features by Kellert (2008) was a landmark advance in biophilic design, the elements and attributes list itself is also in need of further justification of their individual and group importance in the interior. Additionally, this research was conducted exclusively in the southeast United States and may be less globally generalizable. Child and adolescent patients' perspectives regarding their preference for play spaces and features could be an additional focus of future research to broaden the current findings.

The research supporting the importance of finding greater understanding of biophilia and its application in the interior highlighted the previous lack of available frameworks. The resulting importance of an instrument like the BDM is for designers or other experts to have a tool for identifying nature-based features. By moving through the identification process with the use of the BDM, it fosters a more thorough knowledge of the variety of features available for biophilic inclusion. This knowledge can further influence the design decision-making process to focus on nature-based feature integration and support evidence-based design decisions. The BDM thus offers a valuable tool for designers and those invested in adapting the interior to optimize health and wellness through biophilic inclusion.

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Note

1. Permission to use the BDM instrument must be granted from the first author.

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