ArchNet IJAR
International Journal of Architectural Research

BIOPHILIC DESIGN PATTERNS
Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment

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Abstract
This paper carries forth the conceptual framework for biophilic design that was first laid out by Cramer and Browning in Biophilic Design (2008), which established three categories meant to help define biophilic buildings – Nature in the Space, Natural Analogues and Nature of the Space – and a preliminary list of "biophilic conditions". New research and insights from the neurosciences, endocrinology and other fields have since helped evolve the scientific basis for biophilic design. This paper begins to articulate this growing body of research and emerging design parameters in architectural terms, so that we may draw connections between fields of study, highlight potential avenues for future research, evolve our understanding of biophilic design patterns, and capture the positive psychophysiological and cognitive benefits afforded by biophilia in our design interventions.

Keywords: biophilia; biophilic design; pattern language; prospect-refuge theory; mystery; complexity and order; thermal comfort

INTRODUCTION
Biophilia is the deep-seated need of humans to connect with nature. It helps explain why crackling fires and crashing waves captivate us; why a view to nature can enhance our creativity; why shadows and heights instill fascination and fear; and why gardening and strolling through a park have restorative healing effects. Biophilia, as a hypothesis, may also help explain why some urban parks and buildings are preferred over others. For decades research scientists and design practitioners have been working to define aspects of nature that most impact our satisfaction with the built environment. But how do we move from research to application in a manner that effectively enhances health and well-being, and how should efficacy be measured?

As new evidence emerges, the relationships between nature, science and the built environment are becoming easier to understand old wisdom and new opportunities. The scope of this paper, however, limits its perspective to identifying universal issues, rather than situational or sector-specific issues within health and the built environment. This is due to the huge volume of research appropriate to each industry sector that would be required to validate such a paper and would likely be enough content to formulate a book or even several volumes. This paper therefore presents 3 categories and 14 patterns of biophilic design in a manner reflective of the nature-health relationships most prominent in the built environment. We focus on the patterns for which evidence has shown, at least to some degree, to impact our cognitive capacity to enhance and maintain a healthy, life experience through a connection with nature.

The design patterns have been developed from empirical evidence and interdisciplinary analysis of more than 500 peer-reviewed articles and books. The patterns have a wide range of applications for both interior and exterior environments, and are meant to be flexible and adaptive, allowing for project-appropriate implementation. From a designer's perspective, biophilic design patterns have the potential to re-position the environmental quality conversation to give the individual’s needs equal consideration alongside conventional parameters for building performance that have historically excluded health and well-being.

The intent is for this paper is to serve as a catalyst for discussing biophilic design implementation; establishing more robust quantitative and qualitative parameters, where appropriate; identifying where greater research is needed; identifying potential methods and tools to account for variables and to measure or track efficacy. This all, so that we may better capture the benefits afforded by biophilia in our design interventions.

METHOD

The incorporation of nature into the human environment can be found in the earliest man-made structures, and cultures around the world have found ways to bring nature into homes and public spaces. It has been poetically expressed for millennia and scientifically explored for decades. As such, biophilic design is not a new phenomenon; rather, it is the codification of human intuition for what makes a space a good place for humans.

Good biophilic design draws from nature in a manner that is equally inspirational and restorative without disturbing the functionality of the space to which it is integral. How that balance is achieved may differ for particular user groups, building types, or geographical regions, but the science that informs the quality or condition of a healthy space remains relatively universal human response. To articulate what this means for the built environment, our methodology for defining 14 patterns is discussed here in terms of (1) familiar precedents for patterns in the design community, (2) three nature-health relationships, and (3) three nature-design relationships.

Pattern As Precedent

The descriptive term 'pattern' is being used for three reasons: To propose a clear and standardized terminology for biophilic design; to avoid confusion with multiple terms (metric, attribute, condition, characteristic, typology, etc.) that have been used to explain biophilia; and to maximize accessibility for designers and planners by upholding familiar terminology.

The use of spatial patterns is inspired by the precedents of *A Pattern Language* (Alexander, Ishikawa, Silverstein et al., 1977), *Designing with People in Mind* (R. Kaplan, S. Kaplan, & Ryan, 1998) and *Patterns of Home* (Jacobson, Silverstein & Winslow, 2002). Alexander et al. (1977) brings clarity to this intent with his explanation that patterns "…describe a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice."

Alexander’s work built on the tradition of pattern books used by designers and builders from the eighteenth century onward, but his work focused on the psychological benefits of patterns and included descriptions of the three dimensional spatial experience, rather than the aesthetic focus of previous pattern books. These fourteen patterns of biophilic design focus on psychological, physiological and cognitive benefits.

A Framework For Biophilic Design

Nature-health relationships in the built environment: There are three overarching health responses in biophilia that help explain how individuals interact with their environment: cognitive, physiological and psychological. Much of the evidence for biophilia can be linked to research in one or more of these response areas. The baseline condition for each of these responses also influences how our environment impacts us and to what degree.

Health responses are of specific interest to the designer, because they influence how an individual might experience their design, and to planners and policy makers, because they influence public health and equitable access to nature and its benefits.

Nature-design relationships in the built environment: Current theories state that contemporary landscape preferences are a result of human evolution, reflecting the innate landscape qualities that enhanced survival for humanity through time. These evolutionary theories include the biophilia hypothesis (Wilson, 1993; 1984), the savanna hypothesis (Orians & Heerwagen, 1992), the habitat theory and prospect-refuge theory (Appleton, 1975), and the preference matrix (R. Kaplan & Kaplan, 1989). More recently, Heerwagen (2006) laid out a framework for “features and attributes of buildings linked to well being needs and experiences” reflecting these relationships in human-centric terms; and according to Cramer and Browning (2008), human-nature relationships tend to fall into three broad experience categories: nature in the space, natural analogues, or nature of the space.

Nature in the Space describes the presence and diversity of plant life, water bodies, animal species, and other elements from nature within the built environment. Seven patterns related to these interactions have been identified: [1] Visual connection with nature, [2] Non-visual connection with nature, [3] Non-rhythmic sensory stimuli, [4] Access to thermal and airflow variability, [5] Presence of water, [6] Dynamic and diffuse light, and [7] Connection with natural systems.

Natural Analogues are objects, materials, colors, shapes, patterns and algorithms that evoke nature. Broadly speaking, analogues can be characterized in architecture and design as representational artwork, ornamentation, biomorphic forms and natural materials. Three Natural Analogue patterns have been identified: [8] Biomorphic forms and patterns, [9] Material connection with nature and [10] Complexity and order.

Nature of the Space refers to different spatial configurations and associated psychological and physiological responses they engender. Four Nature of the Space patterns have been identified: [11] Prospect, [12] Refuge, [13] Mystery and [14] Risk/Peril.

While informed by science, biophilic design patterns are not formulas; they are meant to inform, guide and assist in the design process and should be thought of as another tool in the designer’s toolkit. The purpose of defining these patterns is to articulate connections between aspects of the built and natural environments and how individuals react to and benefit from them.

RESULTS

The results of this compilation of research are discussed here for six of the fourteen patterns: [1] Visual connection with nature [2] Non-visual connection with nature, [4] Access to thermal and airflow variability, [5] Presence of water, [10] Complexity and order, [11] Prospect and [13] Mystery. Emerging design parameters are highlighted.

This collected evidence leads us to deduce that good biophilic design could have a number of positive impacts. Some of these include enhance productivity and performance and have a positive impact on attention restoration and stress reduction (e.g., van den Berg et al., 2007); increase positive emotions and reduce negative emotions (e.g., Hartig et al., 1991); relaxation of the brain, ocular muscles and lenses; as well as lowering of diastolic blood pressure and stress hormone (i.e., cortisol) levels in the blood stream (e.g., Steg, 2007; Park et al., 2009).

Pattern 1: Visual Connection With Nature

A VISUAL CONNECTION WITH NATURE is characterized as a view to living systems and natural processes.

The VISUAL CONNECTION WITH NATURE pattern is derived from data on (1) visual preference and responses to views to nature showing reduced stress, more positive emotional functioning, and improved concentration and recovery rates, and (2) adaptation to windowless spaces showing that people intuitively add nature content, and respond positively to simulated nature (although not as strongly as to real nature).

There is evidence for stress reduction related to both experiencing real nature and seeing images of nature (e.g., Grahn & Stigsdotter, 2010; Bloomer, 2008; Kahn, Friedman, Gill et al., 2008; Hartig et al., 2003), that natural environments are generally preferred over built environments (e.g., van den Berg, Koole & van der Wulp, 2003; Hartig, 1993; R. Kaplan &

Kaplan, 1989; Knopf, 1987; Ulrich, 1983), and that access to biodiversity may be more beneficial to our psychological health than access to land area (Fuller, Irvine, Devine-Wright et al., 2007).

Visual preference research by Orians and Heerwagen (1992) indicated that universally the preferred view is looking down a slope to a scene that includes copses of shade trees, flowering plants, calm non-threatening animals, indications of human habitation, and bodies of clean water.

A study by van den Berg et al. (2003) observed particiants with high levels of stress had higher preferences for natural environments and lower preferences for urban built environments. This is supported by research from Biederman and Vessel (2006) which concluded that (a) viewing scenes of nature stimulates a larger portion of the visual cortex than non-nature scenes and triggers more pleasure receptors in the brain; and that (b) repeated viewing of real nature, unlike non-nature, does not significantly diminish the viewer's level of interest over time.

Barton and Pretty (2010) argued that positive impact on mood and self-esteem occurs most significantly in the first 5 minutes of exercise within a green space; whereas, Brown, Barton and Gladwell (2013) report that viewing nature for 10 minutes prior to experiencing a mental stressor stimulated heart rate variability and parasympathetic activity (i.e., regulation of internal organs and glands that support digestion and other activities that occur when the body is at rest), while Tsunetsugu and Miyazaki (2005) showed that viewing a forest scene for 20 minutes after a mental stressor returned cerebral blood flow and brain activity to a relaxed state.

According to Fuller, et al. (2007), the psychological benefits of nature increase with higher levels of biodiversity. The same study stated that an increase in these benefits came with an increase in biodiversity and not with an increase in natural vegetative area.

The inclusion of real nature is often difficult to achieve in the built environment. Friedman, Freier and Kahn (2004) hypothesized that simulated nature could have the same physiological benefits as exposure to real natural elements or environments; this was later invalidated by Kahn et al. (2008) who, in a study tracking the heart rate recovery from low-level stress of participants working in an office environment, concluded that a glass window with a nature view was, on average, 1.6 times more restorative than each of the other two conditions a) a plasma screen with high-definition video of the same nature view, and b) a blank wall. The physiological recovery was also greater with increased window viewing time, and while participants looked at the window and plasma screen approximately the same number of times, duration of viewing times was significantly greater for the real window (median = 622.0 seconds) than the plasma (median = 491.5s) or blank wall (median = 55.5s).

This body of research suggests that visual connections to even small instances of nature can be restorative; an important finding given the limitations on and demands for space within urban and interior settings. We can identify emerging design parameters:

- Visual connections with nature can reduce stress, and improve mood and self-esteem (van den Berg et al., 2003; Biederman & Vessel, 2006; Fuller et al., 2007; Kahn et al., 2008; Barton & Pretty, 2010)
- Prioritize real nature over simulated nature, which is better than no nature (Kahn et al., 2008)
- Prioritize biodiversity over acreage (Fuller et al., 2007)
- Prioritize or enable exercise opportunities that are in proximity to green space (Barton & Pretty, 2010)
- Support exposure to nature for at least 5-20 minutes per day (Tsunetsugu et al., 2013; Barton & Pretty, 2010)

Pattern 2: Non-visual Connection With Nature

NON-VISUAL CONNECTION WITH NATURE is characterized by auditory, haptic, olfactory, or gustatory stimuli that engender a positive reference to nature.

The NON-VISUAL CONNECTION WITH NATURE pattern is derived from data on reductions in systolic blood pressure and stress hormones (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003; Orsega-Smith, Mowen, Payne et al., 2004; Ulrich, Simons, Losito et al., 1991), cognitive performance and exposure to sound and vibration (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004), and perceived improvements in mental health and tranquility as a result of non-visual sensory interactions with non-threatening nature (Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003; Li, Kobayashi, Inagaki et al., 2012).

Research by Alvarsson et al. (2010) suggested that nature sounds, when compared to urban noise, allow for physiological and psychological restoration to occur up to 37% faster after exposure to a psychological stressor. Further support is provided by Mehta et al. (2012), who documented that moderate (70 decibels) ambient noise had a greater positive impact on creative performance than did exposure to low (50 decibels) or high (>85 decibels) ambient noise.

In a study relating aromatherapy and post-anesthesia care, Kim et al. (2007) reported 45% less morphine and 56% fewer analgesics used among patients who underwent aromatherapy after surgery. A study by Li et al. (2012) also found that phytoncides (essential oils from trees) had a positive effect on human immune function both in vitro and in vivo.

Hunter et al. (2010) argue that experiencing visual and non-visual stimuli simultaneously changes where in the brain the non-visual senses are interpreted; whereby, if both stimuli are connections with nature, a larger portion of the brain becomes excited and the combined psychophysiological response is more impactful than two responses in isolation. Hunter et al. (2010) also observed that vehicle traffic and ocean waves can have a very similar sound pattern. In an experiment using a synthesized sound that replicated this sound pattern, participants processed the sounds in different portions of the brain depending on whether they were watching a video of waves or of traffic. The sound was considered pleasurable and enhanced the experience when experienced with the video of waves, and not when experienced with traffic.

From this body of work, we can identify emerging parameters:

- Small or momentary interventions with non-visual sensory stimuli can have a positive health impact (Li et al., 2012; Alvarsson et al., 2010; Kim et al., 2007).
- Prioritize nature sounds over urban sounds to engender physiological and psychological restoration (Alvarsson et al., 2010).
- Use moderate ambient noise based on nature sounds to enhance creative performance (Mehta et al., 2012).
- To maximize potential positive health responses, design for visual and non-visual connections with nature to be experienced simultaneously (Hunter et al., 2010).

Pattern 4: Access To Thermal And Airflow Variability

ACCESS TO THERMAL AND AIRFLOW VARIABILITY can be characterized as ambient qualities – air temperature, relative humidity, airflow across the skin, and the radiant temperature of surrounding surfaces – that in combination prompt feelings of comfort similar to those experienced in nature.

The ACCESS TO THERMAL AND AIRFLOW VARIABILITY pattern has evolved from research measuring the effects of natural ventilation, its resulting thermal variability, and worker comfort, well-being and productivity (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005; Heschong, 1979), physiology and perception of temporal and spatial alliesthesia (pleasure) (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002), Attention Restoration Theory and impact of nature in motion on concentration (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989) and, generally speaking, a growing discontent with the conventional approach to thermal design, which focuses on trying to achieve a narrow target area of temperature, humidity and air flow while minimizing variability (e.g., de Dear, Brager & Cooper, 1997).

Heerwagen (2006) explained that evidence has shown that people like moderate levels of sensory variability in the environment, including variation in light, sound and temperatures, (e.g., Humphrey, 1980; Platt, 1961), and that an environment devoid of sensory stimulation and variability can lead to boredom and passivity (e.g., Schooler, 1984; Cooper, 1968).

Early studies in alliesthesia indicate that pleasant thermal sensations are better perceived when one's initial body state is warm or cold, not neutral (e.g., Mower, 1976), which corroborates more recent studies (e.g., Arens et al., 2006) reporting that a temporary over-cooling of a small portion of the body when hot, or over-heating when cold, even without really impacting the body's overall core temperature, is perceived as highly comfortable.

According to Attention Restoration Theory, elements of "soft fascination" such as light breezes or other natural movements can improve concentration (Heerwagen & Gregory, 2008; S. Kaplan, 1995). This is supported by the work of Wigö (2005), which reported that changes in ventilation velocity can have a positive impact on comfort, with no negative impact on cognitive function, while also offering the possibility of a slight increase in the ability to access short term memory; and research by Elzeyadi (2012), which showed that a gradient of thermal conditions within a classroom can lead to better student performance.

From this body of work, we can identify emerging parameters:

- Incorporate airflow and thermal variability to improve user comfort. But, how much variability and what velocities and frequencies are best for upholding a positive health impact (Wigö, 2005)?
- Temporal and spatial alliesthesia – conditioning the individual (e.g, hands, feet) rather than the space – may be more effective than conventional tactics (i.e., thermal uniformity) for achieving thermal comfort and satisfaction (Parkinson et al., 2012; Zhang et al., 2010; Arens et al., 2006; Zhang, 2003; de Dear & Brager, 2002; Mower, 1976).
- Provide features that allow users to easily adapt and modify their perceived thermal conditions of their environment will increase the range of acceptable temperatures by two degrees Celsius above and below the conventional parameters for thermal comfort (Nicol & Humphreys, 2002).

Pattern 5: Presence Of Water

PRESENCE OF WATER is a condition that enhances the experience of a space through the seeing, hearing or touching of water.

The PRESENCE OF WATER pattern has evolved from research on visual preference for and positive emotional responses to environments containing water elements (Windhager, 2011; Barton & Pretty, 2010; White, Smith, Humphryes et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Orians & Heerwagen, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983); reduced stress, increased feelings of tranquility, lower heart rate and blood pressure, and recovered skin conductance from exposure to water features (Alvarsson, Wiens, & Nilsson, 2010; Pheasant, Fisher, Watts et al., 2010; Biederman & Vessel, 2006); improved concentration and memory restoration induced by complex, naturally fluctuating visual stimuli (Alvarsson et al., 2010; Biederman & Vessel, 2006); and enhanced perception and psychological and physiological responsiveness when multiple senses are stimulated simultaneously (Alvarsson et al., 2010; Hunter et al., 2010).

Visual preference research by Orians and Heerwagen (1993) indicates that a preferred view contains bodies of clean water. Research by Jahncke et al. (2011), Karmanov and Hamel (2008) and White et al. (2010) exhibited that natural scenes without a water body, and urban scenes with water elements, exhibit near equal health benefits to participants; whereas, experiences of unnatural or urban scenes generally engender less pleasurable or restorative effects. This is further supported by Alvarsson et al. (2010) and Pheasant et al. (2010), who showed that auditory access and perceived or potential tactile access to water reduced stress in participants; and by Barton and Pretty (2010), who concluded that activities conducted in green spaces with the presence of water generated greater improvements in both self-esteem and mood than green environments without the presence of water.

Emerging parameters:

- Water should be perceived as clean (Orians and Heerwagen, 1992).

- Prioritize a multi-sensory water experience (Alvarsson et al., 2010; Hunter et al., 2010; Pheasant et al., 2010).
- Prioritize naturally fluctuating water movement over predictable movement or stagnancy (Alversson et al., 2010; Biederman & Vessel, 2006).

Pattern 10: Complexity And Order

COMPLEXITY AND ORDER is characterized by the presence of rich sensory information that is configured with a coherent spatial hierarchy, similar to the occurrence of design in nature. In architecture and landscape, the experience is interpreted by S. Kaplan (1988:48) as "how much is 'going on' in a particular scene, how much there is to look at".

The COMPLEXITY AND ORDER pattern is derived from research on fractal geometries and preferred views (Salingaros, 2012; Hägerhäll, Laike, Taylor et al., 2008; Hägerhäll, Purcella, & Taylor, 2004; Taylor, 2006); the perceptual and physiological stress responses to the complexity of fractals in nature, art and architecture (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988); and the predictability of the occurrence of design flows and patterns in nature (Bejan & Zane, 2012).

A familiar challenge in the built environment is in identifying the balance between an information rich environment that is interesting and restorative, and one with an information surplus that is overwhelming and stressful. Empirical evidence for the associative relationships between the patterns, structures, flows and rhythms – that provide, support and organize information – and human perception and physiological health, is most evidently revealed in studies of the occurrence of fractal patterns and dimensions.

The research of Joye (2007), Taylor (2006) and others has repeatedly correlated fractal geometries in nature with those in art and architecture, but as expounded by Salingaros (2012), there are opposing opinions over which fractal dimension is optimal for engendering a positive health response, whether an optimal ratio exists – the preferred fractal dimension is potentially quite broad (D=1.3-1.8) depending on the application – or if such an optimal ratio is even important to identify as a design metric or guideline.

An alternative perspective is to assess hierarchy of iterations of fractal geometry. Nested fractal designs expressed as a third iteration of the base design (i.e., with scaling factor of 3) are more likely to achieve a level of complexity that conveys reduces stress (Salingaros, 2012). The third iteration as a design quality is lost in much of modern architecture, which tends to limit complexity to the second iteration.

While mid-range fractal dimensions may be preferred, at either end of the spectrum, Hägerhäll et al. (2008), Taylor (2006) and others have reported that high-dimensional fractal artwork and overly complex environments can result in psychological stress and even nausea. According to J. H. Heerwagen and R. S. Ulrich, occupants in a U.S. Navy office in Mississippi reported nausea, headaches and dizziness, symptoms frequently associated with poor indoor air quality or poor ventilation. It was determined that the interaction of multiple wall paper patterns, complex patterns in carpets and moiré patterns in seating fabrics caused surfaces to appear to move as occupants walked through the space and therefore caused extreme visual perception problems (Heerwagen, personal communication, March 2014).

Empirical data on the health impacts of viewing or otherwise experiencing instances of COMPLEXITY AND ORDER is limited, but from this body of research a few emerging parameters:

- Fractal structures with iterations of three will be more impactful than a limiting design to two iterations (e.g., Salingaros, 2012).
- Fractal geometries with a mid-range dimensional ratio (broadly speaking, D=1.3-1.8) are generated in nature with relative profundity and should be more readily applied to architecture and design.
- Use fractal geometries in artwork (from realism to abstract); in building materials (e.g., wood grain, stone) for exposed structure elements, interior finishes, or components of the

façade; in the building skyline; and in species selection for landscape views (Joye, 2007; S. Kaplan, 1988).
- Establish a balance between complexity and order (Kellert, 2008).

Pattern 11: Prospect

PROSPECT is a spatial condition characterized by the presence of an unimpeded view over a distance for surveillance and planning.

The PROSPECT pattern is derived from visual preference research and spatial habitat responses, as well as cultural anthropology, evolutionary psychology (e.g., Heerwagen & Orians, 1993) and architectural analysis (e.g., Dosen & Ostwald, 2013; Hildebrand, 1991; Appleton, 1975). Health benefits are suggested to include reduced stress (Grahn & Stigsdotter, 2010); reduced boredom, irritation, fatigue, (Clearwater & Coss, 1991), and perceived vulnerability (Petherick, 2000; Wang & Taylor, 2006); as well as improved comfort (Herzog & Bryce, 2007).

According to Heerwagen and Orians (1993), preference for a prospect condition is strongest when it includes a savannah-like ecosystem with a water body and evidence of human activity or habitation. Petherick (2000) argues that good prospect reduces an individual's fear and stress responses, particularly when alone or in new or unfamiliar environments; and Herzog and Bryce (2007) concluded that distant prospect (>100 feet, >30 meters) is preferred over shorter focal lengths (<20 feet, 6 meter) because it provides a greater sense of awareness and comfort.

For interior spaces or dense urban spaces, prospect is the ability to see from one space to another, and is strengthened when there are clear distinctions and the opportunity to see through multiple spaces (Hildebrand, 1991), but there are potentially endless combinations for applying characteristics of prospect (Dosen & Ostwald, 2013).

Emerging parameters:
- Provide minimum focal lengths of ≥20 feet (6 meters), preferably 100 feet (Herzog & Bryce, 2007).
- Incorporate an information-rich prospect view by designing with or around an existing or planned savannah-like ecosystem, body of water, and evidence of human activity or habitation (Heerwagen & Orians, 1993).
- Limit opaque partitions (e.g., workplace conditions, landscape hedges) to 42 inches in height.

Pattern 13: Mystery

MYSTERY is a spatial condition characterized by the promise of more information manifested by the presence of partially obscured views or other sensory stimuli that fascinate and entice the individual to travel deeper into the environment (Herzog & Bryce, 2007; Ikemi, 2005; R. Kaplan & Kaplan, 1989).

The MYSTERY pattern is framed by R. Kaplan and S. Kaplan's (1989) proclamation that people have two basic needs in environments: to understand and to explore. Herzog and Bryce (2007) also clarify that these 'needs' are to occur "from one's current position" in order to engender a sense of mystery.

The characteristics of the pattern are derived from visual preference and perceived danger (Herzog & Bryce, 2007; Herzog & Kropscott, 2004; Nasar, & Fisher, 1993); and supported by research on pleasure responses to anticipatory situations (Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001).

Mystery engenders a strong pleasure response within the brain that may be a similar mechanism to that of anticipation (Biederman, 2011), which Blood and Zatorre (2001) and Salimpoor et al. (2011) hypothesize is an explanation for why listening to music is so pleasurable – in that we are guessing what may be around the corner. A quality mystery condition does not engender a fear response; the conditions that differentiate between fear and pleasure center around the visual depth of field. Research by Herzog and Bryce (2007) exhibited that an obscured view with limited visual access can lead to unpleasant surprises, whereas a greater visual access, with a medium (≥20 ft) to high (≥100 ft) depth of field is preferred.

A study by Ikemi (2005) exhibited that a good mystery condition obscures the boundaries and a portion of the forward plane of the subject object, room, building, outdoor space, or other information source, thereby enticing the user to explore the space, to see more of the partially obscured subject. Emerging parameters:

- Views are medium (≥20 ft) to high (≥100 ft) depth of field (Herzog & Bryce, 2007)
- At least one edge of the focal object is obscured, preferably two edges (Ikemi, 2005)

DISCUSSION AND FUTURE DIRECTIONS

This review highlights some emerging design parameters for implementing biophilia, yet there is still a need for understanding where numeric metrics are necessary for designing for positive health impacts, and where qualitative attributes are more appropriate. Frequency and duration of exposure to these patterns of biophilic design, as well as persistence of health impact are key topics for additional research. Similarly, repetition – how often a pattern can be experienced and continue to elicit a response – and scope and scale – what is the intervention trying to achieve and how big the physical intervention needs to be to elicit a response – are also points of consideration for additional research.

Frequency and duration of experience: Planners, architects and designers want to understand how often the biophilic experience is needed (Elzeyadi, 2012), and what the minimal or optimal duration of an experience is needed to engender a positive psychological or physiological response (Brown, Barton & Gladwell, 2013; Barton & Pretty, 2010; Tsunetsugu & Miyazaki, 2005).

Persistence of health response: The body of evidence cited here is a sampling of the work conducted that has established a basis for our understanding of nature-design and nature-health relationships. However, as far as the authors are aware, little if any empirical evidence exists showing whether, and for how long, positive health responses persist after a biophilic intervention is experienced. From a designer's perspective, for example, understanding how long a positive physiological response persists once a fractal pattern is no longer observed (Hägerhäll et al., 2004), might influence where in a space it is placed, such as to maximize frequency and duration, or to ensure exposure to the greatest number of people possible.

Repetition of experience: A common concern with architects is whether a biophilic experience, particularly the Mystery pattern, is likely to become attenuated as an individual becomes familiar with the environment. One perspective is to incorporate design elements that vary or change over time (i.e., refreshing the promise for new information), such as through cycling spatial content, providing variability in light (diurnal or electric) and shadows, or seasonal patterns (e.g., vegetation, fragrances, etc). Understanding whether change and variation is important to overcome attenuation and maintain a positive health impact could potentially influence design complexity from the conceptual stage through to operation and maintenance.

Scope and scale of intervention: Understanding whether there is a quantity or percentage of objects in a view shed that must be at a specific fractal ratio to engender an adequate positive health response (Hägerhäll et al., 2004) could inform a range of design decisions, for example, plant selection for landscapes and gardens, interior finishes, and building orientation for maximum value views. Additionally, interest among planners and designers is growing to engage in a more sensory-rich experience with the built environment; therefore, it would help to understand whether mechanisms of perceptual pleasure be identified for our non-visual systems, particularly auditory (Hunter et al., 2010; Biederman & Vessel, 2006), and how much greater the health impact becomes when the experience of water, for example, is either multi-sensory or physically bigger.

Other directions include a broadening the scope to integrate with building systems by asking, for example, whether acoustic properties of a space can be enhanced by integrating water sounds to diffuse excessive noise to contribute to both increased worker productivity and mitigation of speech privacy issues.

Research that establishes relationships between multiple patterns, such as between prospect and refuge (e.g., Dosen & Ostwald, 2103; Ljungberg et al., 2004), or visual and non-visual connections with nature (e.g., Hunter et al., 2010), and especially patterns from two different categories (i.e., Nature in the Space, Natural analogues, Nature of the Space), tends to be contextually informative from a design implementation perspective. The work of Dosen and Ostwald (2103), Ljungberg et al. (2004), and Hunter et al. (2010) also brings us to question which other pattern relationships are being studied, and what additional opportunities are there for integrative research and design.

CONCLUSION

Establishing distinct patterns is not an attempt to create cookie-cutter solutions for human-centric design, but rather to provide a framework through which any variable, with the appropriate care, could be adapted with locally appropriate and user-centered biophilic design. Appropriate solutions will result from understanding what suits the unique programmatic needs of a space and its intended user group (R. Kaplan et al., 1998). There also needs to be an understanding of whether this holds true across ecosystem types and varying definitions of “nature”, how much nature is needed to define a condition, and which factors contribute to positive health effects that persist over time.

The body of literature cited here is part of a nascent effort to gather evidence recording health responses to nature experiences. Some aspects of biophilia are inherently difficult to quantify, and due to the relative infancy of the field of biophilic design, we recognize there is a significant need for additional research.

Tracking and measuring efficacy of biophilic patterns and parameters or metrics can be challenging. This is due to the high number of variables, shifting baselines, the unpredictability of the built and natural environments, as well as the highly invasive nature of some data collection techniques. Factors such as genetics, diet, level of exercise and socio-economic status each impact baselines for measuring and mitigating stress (Bilotta & Evans, 2007). What qualifies as ‘nature’ is in a state of perpetual flux across cultures and generations, making it difficult to establish a baseline from which to build supporting evidence (Barton & Pretty, 2010; Kahn, 2009; Hägerhäll et al., 2008; Kahn et al., 2008; Steg et al., 2007; van den Berg & Konijnendijk, 2007).

As this review of evidence shows, the built environment can have a positive, neutral or negative effect on an individual, and responses may differ with the user’s health baseline; the frequency and duration of the experience; socio-cultural norms and expectations; the user’s experience up to that point; and how the individual perceives and processes the experience.

While this breadth of research continues to evolve, definitions, metrics (Lercher, 2003) and guidelines are needed for planning (Tsunetsugu et al., 2013) and design implementation (Dosen & Ostwald, 2013), monitoring and validation of efficacy. Widespread accessibility to and implementation of biophilic design patterns could help re-focus the design process on the individual, while capturing the economic benefits of nature in the built environment (Terrapin Bright Green, 2012; Heerwagen, 2006). As more of the world’s population shifts to urban settings, the need for biophilic design will become more important.

ACKNOWLEDGEMENTS

This review was supported by Terrapin Bright Green LLC. We thank Stefano Serafini and the International Society of Biourbanism for providing guidance and encouragement.

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