Colour, Light, and Materiality: Biophilic Interior Design Presence in Research and Practice

Beth McGee,¹ Nam-Kyu Park²

¹Georgia Southern University
USA
²University of Florida
USA

Abstract

The biophilic design hypothesis uses nature-based environmental design for optimising people's health and well-being. Stephen Kellert in 2008 developed a list of biophilic attributes that was further refined in the Biophilic Interior Design Matrix (BID-M) to specifically support the interior application of biophilic design for health and well-being. The present study further investigates biophilic interior design using the BID-M language and the key interior design components colour, light, and materiality. The first part of the study reviewed four decades of literature related to biophilia and colour, light, and materiality to investigate a total of 19 publications. The second part of the study explored the perceptions of 23 design practitioners' and the use of biophilia related to colour, light, and materiality in their practice. For the first time, evidence was identified about colour, light, and materiality being linked to biophilic design and the attributes in the BID-M. The study results showed colour preferences were the most frequently identified theme, and practitioners used a variety of biophilic attributes in their practice. The top attributes shared by both the literature review and practitioners were the abstraction of nature, composition, natural light, and natural materials. This finding shows that there is a focus on biophilic attributes in both research and practice, however, there are still many attributes that have not been linked to research and are not being used in practice. Further inquiry is needed to better understand how biophilic design can be more diversely integrated for optimal nature-like interior environments.

Keywords: colour, light, materiality, biophilic interior design, practitioner's perception, biophilic interior design matrix

Correspondence Address: Beth McGee, Interior Design, School of Human Ecology, Georgia Southern University, PO Box 8034, Statesboro, GA, USA. E-mail: blsmcgee@gmail.com
**Introduction**

Recent events with a global pandemic have caused a new focus on the importance of incorporating nature into the built environment (Carabelli, 2020). Even previous to the recent pandemic, there had been a growing desire to incorporate nature-based elements into the built environment known as biophilic design (Kellert et al., 2008). Biophilic design is based on biophilia, which is the innate need to connect with nature or natural representations and supports neurological nourishment with documented physical, psychological, and spiritual outcomes (Eisen et al., 2008; Kahn & Kellert, 2002; Kaplan & Kaplan, 1989; Louv, 2011). Experiencing nature has positively been associated with improved mental, physical, and emotional states (Abkar et al., 2010; Korpela et al., 2014; Ohly et al., 2016). Biophilia was notably proposed by E. O. Wilson (1984) based upon his study of biology and earlier work in the late 1970s directing that hypothesis. Biophilia has since been applied to designing with nature, known as biophilic design (Yin et al., 2018). It uses evidence-based design principles to support nature-based environmental design for optimising people’s health and well-being (Gray & Birrell, 2014; Kellert, 1993). This approach attempts to offer connections with the natural environment through nature-based design decisions. The Biophilic Interior Design Matrix (BID-M) was developed to support the interior application of biophilic design for health and well-being (McGee et al., 2019). The matrix includes attributes that support various nature-based design features and was the reference list of biophilic features used in this study.

A holistic consideration of interior design includes colour, light, and materiality as pivotal sensorial considerations for interior environments (Kilmer & Kilmer, 2014). These three factors are interrelated in design; they occur together in a space. Nevertheless, it was unknown how these three features are being applied in relation to biophilic features and how existing research supports biophilic features. A literature review was used to identify relevant research. At the same time, the use of colour, light, and materiality was explored through case studies of interior design practitioners in the United States. This study aimed to answer the following questions: 1) What evidence for colour, light, and materiality can support biophilic design? 2) How do design practitioners apply biophilic design using colour, light, and materiality to their projects? 3) What is the relation between application and evidence of biophilic design within colour, light, and materiality?
Biophilic Design and Biophilic Interior Design Matrix

To situate biophilic design in context, we can look at the term biophilia through the lens of the Greek origin, *bio* meaning life and *philia* meaning a platonic love (Orr, 1993). The term biophilic design developed at a time when people were designing spaces that increasingly separated people from the natural world. Totaforti (2018) describes the development of biophilic design as a rejection of that approach. Instead, biophilic design is where the “mind and the human body develop within a ‘sensory rich world’ that is fundamental to people’s health and intellectual, emotional and spiritual well-being” (p. 2). Understanding the human need for nature has since expanded into a growing body of knowledge that has found cognitive and physiological health benefits to connecting with nature. These include direct and indirect connections to nature that can occur within the built environment. Natural and simulated environments are both seen offering stress reduction with the natural environments for significantly greater effect (Kjellgren & Buhrkall, 2010). Task performance has also been found to increase with direct experience in the interior (Raanaas et al., 2011). Indirect contact can improve attention, be invigorating, and increase long-term memory (Pilotti et al., 2015); even in a virtual reality simulation, reductions in blood pressure and increased cognitive function can be seen (Yin et al., 2018). Also, short-term visual contact alone can be restorative (Ulrich, 1992). Nanda et al. (2012), in a review of neuroscience articles on emotional states and characteristics of images, found that viewing some types of nature images lowered blood pressure and heart rate. These images were noted to be more restorative.

In 2008, Stephen Kellert attempted to operationalise biophilia with a list of 72 design attributes organised among six elements. Kellert’s list was refined into 54 attributes related to interior design in the BID-M (McGee et al., 2019). The six-element categories are labelled: *actual natural materials, natural representations, natural patterns and processes, colour and light, place-based relationships, and human-nature relationships* (see Table 1).

Evidence is beginning to show that “people’s physical and mental well-being remains highly contingent on contact with the natural environment, which is a necessity rather than a luxury for achieving lives of fitness and satisfaction even in our modern urban society” (Kellert, 2008, p. 4). However, many people may spend most of their time inside and this limits direct nature contact (Derr & Kellert, 2013;
Klepeis et al., 2001). How interior designers and research has been incorporating biophilic design in terms of colour, materiality, and light is not well understood.

| Table 1 | Biophilic Interior Design 6 elements along with 54 attributes used to assess biophilia in this study |
|---------------------|--------------------------------------------------------------------------------------------------|
| **Element #1** Actual natural features — actual (not images) of natural characteristics in the interior |
| 1 Air                |
| 2 Water              |
| 3 Plants             |
| 4 Animals            |
| 5 Natural materials  |
| 6 Views and vistas   |
| 7 Habitats           |
| 8 Fire               |
| **Element #2** Natural shapes and forms — representations of nature and simulations |
| 9 Botanical motifs   |
| 10 Animal-like       |
| 11 Shells and spirals|
| 12 Curves and arches|
| 13 Fluid forms       |
| 14 Abstraction of nature |
| 15 Inside-outside    |
| **Element #3** Natural shapes and forms — properties derived from natural features and processes |
| 16 Sensory richness  |
| 17 Age, change, and the patina of time |
| 18 Area of emphasis  |
| 19 Patterned wholes  |
| 20 Bounded spaces    |
| 21 Linked series and chains |
| 22 Integration of parts to wholes |
| 23 Complementary contrasts |
| 24 Dynamic balance and tension |
| 25 Natural ratios and scales |
| **Element #4** Colour and light — colour, light and material qualities, and space relationships to nature |
| 26 Composition       |
| 27 Communication     |
| 28 Preference        |
| 29 Engagement        |
| 30 Pragmatics        |
| 31 Natural light     |
| 32 Filtered light    |
| 33 Reflected light   |
| 34 Light pools       |
| 35 Warm light        |
| 36 Light as shape and form |
| 37 Spaciousness      |
| 38 Spatial variety   |
| 39 Space as shape and form |
| 40 Spatial harmony   |
| **Element #5** Place-based relationships — culture together with ecology, rooted in geography |
| 41 Geographic connection to place |
| 42 Historic connection to place |
| 43 Ecological connection to place |
| 44 Cultural connection to place |
| 45 Integration of culture and ecology |
| 46 Spirit of place    |
| **Element #6** Human-nature relationships — paired biological needs of the human relationship to nature |
| 47 Prospect/refuge   |
| 48 Order/complexity  |
| 49 Curiosity/enticement |
| 50 Mastery/control  |
| 51 Attraction/attachment |
| 52 Exploration/discovery |
| 53 Fear/awe          |
| 54 Reverence/spirituality |
**Colour**

According to *Merriam-Webster Dictionary* (2021), the definition of colour is “the aspect of the appearance of objects and light sources that may be described in terms of hue, lightness, and saturation for objects and hue, brightness, and saturation for light sources”. Colour is a concept that “elevates the human experience and transforms space; yet, the process of designing with colour can be quite complex and challenging” (Portillo, 2009, p. 1). Colour can modify our perception of architectural form and even influence subjective impressions of a space (Bosch et al., 2012). Generally, research about colour has focused on colour hue preference which varies among people and over a person’s lifetime (Blumberg & Sloan Devlin, 2006; Dittmar, 2001). This is within a world where “we are surrounded by an ever-changing palette of colour in nature that inspires the principles used in the creation and selection of materials for interior design” (Bosch et al., 2012, p. 13). Thus, colour can be seen as a nature-based part of the material components in a space. However, you cannot see colour unless you also have light.

**Lighting**

Designing with light requires thoughtful layers of lighting applied for function and aesthetics, and when done well, it reveals the beauty of the design and enhances the colours and materials of the space (Livingston, 2014). The quality of natural light especially influences the interior; direct access to natural light has growing research support for its importance on well-being, tied to benefiting circadian rhythm and sleep-wake cycles (Alimoglu & Donmez, 2005; Beute & Kort, 2014). Take away the light, and the spatial experience would be modified.

**Materiality**

Designing with materiality requires attention to the interconnection of the human experience and how properties engage people (Gesimondo & Postell, 2011). Materiality can be highly subjective, such as our preference for a particular material. Object materiality is influenced by its properties. Additionally, “environmental context and cultural bias collectively give materials their broader meaning, while interior space offers a spatial framework for daily experience” (Gesimondo & Postell, 2011, p. 3). Portillo (2009) points out that it is not as important to look at if something is authentically “natural,” like if a faux painted stone wall is less natural than a real stone wall. Looking at the greater impact of the materials on the design and colour palette is most beneficial.
The BID-M list of biophilic attributes can be applied in an interior using either the singular or combined presence of colour, light, and materiality. Colour specifically is included in BID-M biophilic attributes number 26–30, namely composition (26), communication (27), preference (28), engagement (29), and pragmatics (30). Any of the attributes, however, can integrate colour. There are also a few dedicated attributes for light, which are natural light (31), filtered light (32), reflected light (33), light pools (34), warm light (35), and light as shape and form (36). Again, light can influence any design feature and, as such, relates to the success and decisions of many attributes. Materials are present similarly in all the attributes such as sensory richness (16) and age, change, and the patina of time (17) but specifically in natural materials (5). Altogether, colour, light, and materiality offer a strong window into exploring a unique approach to biophilic application.

**Method of Study**

The overarching method for this study included two parts. This study used a complementarity typology in a mixed-method design. Greene et al. (1989) describe this further that “in a complementarity mixed-method study, qualitative and quantitative methods are used to measure overlapping but also different facets of a phenomenon, yielding an enriched, elaborated understanding of that phenomenon” (p. 258). Part one was a literature review that was the first of its kind to explore research on colour, light, and materiality specifically related to their application of biophilic design in the interior environment. In part two, a survey was conducted of design practitioners to understand their lived experiences with biophilic design application, specifically concerning colour, light, and materiality.

**Part one: Literature review**

The identification of evidence for colour, light, and materiality that might support biophilic design began with identifying 66 articles in a group literature search. The next steps followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-P) checklist protocol for a systematic literature review (Shamseer et al., 2015), as illustrated in Figure 1. It is a protocol that provides a set of items for developing and reporting systematic reviews. This review focused on intervention and outcomes regarding empirical research for colour, light, and materiality supporting the biophilic design attributes. The setlist of criteria to search through the University library OneSearch feature or Google Scholar was: Art & Architecture Source, BuildingGreen, Compendex, Dissertations & Theses Global, Materials Research Database, Referex Engineering—
Materials and Mechanical Collection (Engineering Village), Web of Science, and InformeDesign. The search criteria were selected for either those closely related to the built environment or as a broad base for related fields. English articles were used with a publication date range from 1978 to 2018.

In step one, the literature was reviewed for the three keywords of colour, light, and materiality with the additional filter of identifying articles related to biophilic attributes. In step two, duplicates were removed. In step three, the articles were narrowed by topic. This process resulted in 66 articles being reviewed, but after removing duplicates, there were 55 left. Step four removed the grey literature, not related articles, and articles in another language, with 33 left. Three independent reviewers screened these, with two reviewers screening one half of the list and organising alphabetically by title. After another screening, two more articles were removed that did not meet the criteria, for a total of 31 articles relevant for full-text inclusion.

The studies were finally scored in three categories: 1) if the variables used related to one or more of the categories of colour, lighting, and/or materiality, 2) if they related to a biophilic attribute defined according to the BID-M, and 3) a 100-point scale was developed. The scale was used to see if an article addressed both interior design and biophilic features. A 70% score was considered a weak association to both interior design and biophilic features resulting in a weak biophilic strength when the variables used were only indirectly related to biophilia, 80% was considered moderate strength, and 90–100% was considered strong association that the variables used directly related
to biophilia. The reviewers scored each article and then met to finalise any discrepancies. The scoring process and the form used were pilot tested with one article done together among the researchers and as a training tool, then five articles were done independently, and the results were compared. If there was an agreement of at least 70% that the article was related to both biophilic design and interior design, it was retained. There were 11 articles that did not cover both interior design and biophilic design after review and one not being empirical research, so these were removed. This resulted in a total of 19 articles included in the review.

**Part two: Survey of design practitioners**

Part two of this study sought how design practitioners apply biophilic design using colour, light, and materiality to their projects. The respondents for part two were recruited by direct email, snowball sampling, or notification through social media. The data collection included 23 participants, 19 of whom had their undergraduate degree from a CIDA (formerly FIDER) or NAAB accredited program. The length of practice was shared between 2–5 years and 26 years or more (n=7, 30.4%). Ten participants had passed the National Council of Interior Design Qualification (NCIDQ) exam, one the National Council of Architectural Registration Boards (NCARB) and nine people had their LEED accreditation. Corporate design was the most common specialisation (n=12, 51.6%) (see Table 2).

| Practice years | n | % | Certification | n | % | Specialisation | n | % |
|----------------|---|---|---------------|---|---|----------------|---|---|
| <2             | 2 | 8.7 | LEED         | 9 | 38.7 | Corporate    | 12 | 51.6 |
| 2–5            | 7 | 30.4 | NCARB       | 1 | 4.3 | Healthcare   | 7 | 30.1 |
| 6–10           | 4 | 17.4 | NCIDQ       | 10 | 43 | Hospitality | 5 | 21.5 |
| 11–15          | 2 | 8.7 | Well         | 1 | 4.3 | Institution | 2 | 8.7 |
| 16–20          | 1 | 4.3 | State license | 7 | 30.1 | Residential | 6 | 25.8 |
| 21–25          | 0 | 0 | Other*       | 2 | 8.7 | Other       | 6 | 25.8 |
| ≥26            | 7 | 30.4 | -             | - | - | -             | - | - |

*Note: *Other included CSSBB and EBD as well as 1st class Korean Architecture Engineer; *Participants could select more than one answer

An online survey was conducted asking two open-ended questions: 1) how they include biophilia through colour, light, and materiality in projects, and 2) what issues they have faced with using colour, light, and materiality in biophilic features. Content analysis of the open-ended questions categorised responses into themes with the coding jointly assigned by both researchers. The coding process looked at the concept of colour, light, and materiality separately. Each comment was coded regarding each of the three concepts with multiple attributes possible per response.

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| Author                | Biophilic attributes | Colour | Light | Material | Biophilic strength* | Biophilia benefits                                                                 |
|-----------------------|----------------------|--------|-------|----------|---------------------|-------------------------------------------------------------------------------------|
| Campbell (1979)       | Composition, plants, preference | v      |       |          | ++                  | Plants, visual posters, and organisation influence how people feel and how they see the owner of the space |
| Daneshgar-moghaddam & Bahrainy (2014) | Integration of culture and ecology, spirit of place | v      |       |          | ++                  | Spirit of place can benefit from natural features in the built environment inside and outside |
| Dijkstra et al. (2008) | Plants               | v      |       |          | +++                 | Indoor plants add an aesthetic quality that reduced perceived stress                   |
| Eisen et al          | Preference, botanical motifs | v      |       |          | +++                 | Nature representation in artwork for children’s spaces are most preferred, choices should be available |
| Gray & Birell (2014)  | Plants, views and vistas, natural light, natural materials | v      | v     |          | ++                  | Open plan workspace, natural lighting, ventilation, significant plants, prospect, views, recycled materials, and non-synthetic materials for high performing workspace |
| Kim et al. (2017)     | Engagement           | v      | v     |          | ++                  | COAT used for colour quality, luminous environment and circadian action factor varied with finishes |
| Koranteng & Simons (2012) | Natural light, pragmatics | v      |       |          | ++                  | Natural light reduced from architectural and cultural decisions, education needed about benefits of natural light |
| McCoy & Evans (2002)  | Order/complexity, views and vistas, natural materials | v      |       |          | ++                  | Views of natural environments and exposure to natural materials may promote             |
| Odabaşıoğlu & Olguntürk (2015) | Composition, engagement | v      | v     |          | ++                  | Coloured lighting affected perceptions                                                |
| Olguntürk & Demirkaran (2011) | Abstraction of nature | v      |       |          | +                   | Colour in a pattern is principal unifying component                                      |
| Park & Farr (2007a)   | Preference, engagement, warm light | v      |       |          | +++                 | Colour temperature, colour rendering changes with age and warm lighting use, and consideration needed for older populations |
| Park & Farr (2007b)   | Engagement, preference | v      |       |          | +++                 | Perceptions of pleasurable lighting varies by culture                                       |
| Pati et al. (2016)    | Inside-outside, sensory richness | v      |       |          | +++                 | Sky representations over patients beds beneficial for acute stress and anxiety levels     |
| Raanaas et al. (2010) | Plants               | v      |       |          | +++                 | Adding plants to a rehab center benefited wellbeing                                        |
| Rossin (2010)         | Abstraction of nature | v      |       |          | +                   | Biomimetic process added to interior design process to solve problems                   |
| Sanati & Utzinger (2013) | Filtered light, natural light, preference, engagement, master/control reference | v      |       |          | ++                  | Light shelf helpful for increased daylight access, control of blinds important          |
| Tavsan & Sonmez (2015) | Abstraction of nature | v      |       |          | +                   | Biomimicry used as design inspiration for design students                                  |
| Theodorson (2018)     | Natural light, pragmatics | v      |       |          | ++                  | Natural light and views in classrooms need easy to use daylight control                   |
| Vouchilas & Ulasewicz (2017) | Preference | v      |       |          | ++                  | Colour preference in designed objects and spaces influences perception of design         |

* + = low; ** = medium; +++ = high

Table 3: Literature review biophilic design results

Colour, Light, and Materiality
## Results

### Part one: Colour, light, and materiality in biophilic design literature

To answer research question one, a literature review was used to seek evidence for colour, light, and materiality that also related to the biophilic attributes. This literature review summarised 19 articles concerning biophilic design: four on colour, eight on lighting, and nine on materiality; two had dual topics (see Table 3). There were many and diverse benefits noted in the articles, such as using plants to benefit well-being (Raanaas et al., 2010), and light and materials being part of a design solution that found “biophilic design to boost productivity, ameliorate stress, enhance well-being, foster a collaborative work environment and promote workplace satisfaction, thus contributing towards a high performance workspace” (Gray & Birrell, 2014, p. 12204). The results of the thematic data analysis identified 18 themes present in the literature, with engagement and then preference as the most frequently identified themes (see Table 4).

| Biophilic attribute | Biophilic features | Colour | Light | Materiality | Frequency of articles |
|--------------------|-------------------|--------|-------|-------------|----------------------|
| 3                  | Plants            | 4      | 4     |             |                      |
| 5                  | Natural materials | 2      | 2     |             |                      |
| 6                  | Views and vistas  | 2      | 2     |             |                      |
| 9                  | Botanical motifs  | 1      | 1     |             |                      |
| 14                 | Abstraction of nature | 1    | 2     | 3           |                      |
| 15                 | Inside-outside    | 1      | 1     |             |                      |
| 16                 | Sensory richness  | 1      | 1     |             |                      |
| 26                 | Composition       | 1      | 1     | 1           | 3                    |
| 28                 | Preference        | 1      | 3     | 2           | 6                    |
| 29                 | Engagement        | 2      | 5     | 7           |                      |
| 30                 | Pragmatics        | 2      | 2     |             |                      |
| 31                 | Natural light     | 4      | 4     |             |                      |
| 32                 | Filtered light    | 1      | 1     |             |                      |
| 35                 | Warm light        | 1      | 1     |             |                      |
| 45                 | Integration of culture and ecology | 1 | 1 | | |
| 46                 | Spirit of place   | 1      | 1     |             |                      |
| 48                 | Order/complexity  | 1      | 1     |             |                      |
| 50                 | Mastery/control  | 1      | 1     |             |                      |
| **Total**          |                   | 5      | 20    | 17          | 42                   |

*Note: The articles were able to be categorised with more than one biophilic feature*

### Part two: Colour, light, and materiality in design practice

Design practitioners are using a variety of approaches integrating colour, light, and materiality into their projects. Twenty-nine different biophilic attributes were represented in the research,
while 25 were not included (see Table 5). Fifty-nine comments were assigned to colour, 51 for light and 70 for materiality. The top three most common features for each category are described next.

| Biophilic attribute # | Biophilic features                          | Colour | Light | Materiality | Frequency of application |
|-----------------------|---------------------------------------------|--------|-------|-------------|--------------------------|
| 3                     | Plants                                      | 2      | 2     |             |                          |
| 5                     | Natural materials                           | 6      | 6     | 7           | 19                       |
| 6                     | Views and vistas                            | 1      | 1     | 1           | 3                        |
| 9                     | Botanical motifs                            | 1      | 1     | 4           | 6                        |
| 10                    | Animal-like                                 | 1      | 1     | 3           | 5                        |
| 11                    | Shells and spirals                          | 1      | 1     | 3           | 5                        |
| 12                    | Curves and arches                           | 2      | 3     | 5           |                          |
| 13                    | Fluid forms                                 | 2      | 3     | 3           | 8                        |
| 14                    | Abstraction of nature                       | 3      | 2     | 4           | 9                        |
| 15                    | Inside-outside                              | 1      | 1     |             |                          |
| 16                    | Sensory richness                            | 1      | 3     | 4           |                          |
| 23                    | Complementary contrasts                     | 1      | 1     |             |                          |
| 26                    | Composition                                 | 4      | 1     | 2           | 7                        |
| 27                    | Communication                               | 3      | 1     | 3           | 7                        |
| 29                    | Engagement                                  | 4      | 4     | 3           | 11                       |
| 30                    | Pragmatics                                  | 2      | 4     | 3           | 9                        |
| 31                    | Natural light                               | 9      | 9     |             |                          |
| 32                    | Filtered light                              | 2      | 2     |             |                          |
| 33                    | Reflected light                             | 1      | 1     |             |                          |
| 35                    | Warm light                                  | 1      | 1     | 1           | 3                        |
| 36                    | Light as shape and form                     | 1      | 1     |             |                          |
| 38                    | Spatial variety                             | 1      | 1     |             |                          |
| 40                    | Spatial harmony                             | 1      | 1     | 2           |                          |
| 41                    | Geographic connection to place              | 5      | 4     | 6           | 15                       |
| 42                    | Historic connection to place                | 1      | 1     | 2           |                          |
| 43                    | Ecological connection to place              | 4      | 3     | 6           | 13                       |
| 44                    | Cultural connection                         | 2      | 4     | 6           |                          |
| 45                    | Integration of culture and ecology          | 3      | 2     | 3           | 8                        |
| 46                    | Spirit of place                             | 1      | 1     | 2           |                          |
| 47                    | Prospect/refuge                             | 1      | 1     | 2           |                          |
| 51                    | Attraction/attachment                       | 1      | 1     |             |                          |
| 52                    | Exploration/discovery                       | 1      | 1     |             |                          |
| **Total**             |                                             | **50** | **51** | **70**      | **168**                  |

The most recurring biophilic attributes for colour were (with the number of comments in parenthesis): natural materials (6), geographic connection to place (5), and composition, ecological connection to place, and engagement (4). These were found among the 50 comments assigned to colour with most being unique attributes. These top themes represent colour as most often tied to the composition of the space and the local context through the use of natural materials that bring colour influence. “Colors can be
drawn from natural imagery,” stated Participant 13. Participant 14 commented how they approach biophilic design “by designing an interior that seems appropriate to its location and varying the stated design elements to create a texture as one would find in nature.” Additional participants talked about using nature-based artwork and tying the design concept to the locality for very project-specific design solutions.

The most recurring comments per BID-M attributes for light among the 51 comments that were assigned for light: natural light (9), natural materials (6), and engagement, geographic connection to place, and pragmatics (4). This includes the use of natural light when available and allowing as many people as possible to have close access to it. Manipulating colour temperature, especially warm light was another variable that designers use in their designs. Also, designers use artificial light to mimic natural light through intensity and circadian rhythm systems to align people’s responses more closely with natural ones, engagement. Pragmatics was a common consideration with both maintenance and conservation of energy noted.

The most recurring biophilic attributes commented about materiality among the 70 comments were: natural materials (7), geographic connection to place and ecological connection to place (6) and abstraction of nature, botanical motifs, and cultural connection to place (4). Some of the specific natural materials mentioned (aside from plants specifically mentioned twice) include natural wood, stone, natural fabrics, crafted and rustic materials, and natural artwork. Practitioners also mentioned using organic shapes, patterns, textures. These tactics are represented within the natural patterns and processes element. They also used “layering in terms of materials and views…. symbolic use of colour and images in wayfinding and branding” (Participant 20). Human considerations were also noted, such as creating soft, comfortable, and warm spaces while avoiding sterile spaces. Again, the local context was mentioned, with an example being that the designer would “search [for] locally or culturally related materials, etc.” (Participant 12).

The six biophilic design elements had varied representation in practitioners’ inclusion of biophilia according to the number of comments (see Figure 2). Colour, light, and materiality are grouped into two most common areas, colour and light and place-based relationships with 53 and 46 comments, respectively, out of 168.
The strategies designers used showed attributes such as blending colour, light, and/or materials. Geographic connection to place was a biophilic feature that occurred in all three categories. Next, natural materials and ecological connection to a place were found in two out of three categories. One example of a participant’s comment highlights this:

> We favour using a mix of natural textures (sisal rug, grass-weave wallpaper, wooden blinds). We have a preference for using natural fabrics such as linen, cotton, and silks (when appropriate). Many of our projects include designing custom window treatments, we favour drapes with the use of sheers to bring in more light, but providing some privacy. We specify colour temperatures aiming for 2700–3300K. We select sustainable materials, natural materials, such as real wood furniture (or repurposing existing) as opposed to MDF laminated furniture. Our projects focus on designing for life and durability (excluding kids, pets, and wine). For example, by using real wood furniture, which is durable and can be finished rather than a piece (laminated MDF) that cannot be repaired. Finally, we often purchase and pot up plants to complete the finished project. (Participant 5)

Another participant noted that these biophilic design approaches may “be used as basic design tools in any project” (Participant 3).

The focus of the practitioner’s biophilic inclusion was most common in the element colour and light (32% of comments), while place-based relationships were a close second place (27% of comments) as illustrated in Table 6.
Table 6
Frequency of practitioner comments by biophilic element, referencing the Biophilic Interior Design Matrix (McGee, B. et al., 2019)

| Biophilic element                  | Definition                                                                 | Frequency of comments | (%)  |
|------------------------------------|---------------------------------------------------------------------------|-----------------------|------|
| Actual natural features            | Actual (not images) of real nature characteristics in the interior        | 24                    | 14   |
| Natural shapes and forms           | Representations of nature and simulations                                  | 39                    | 23   |
| Natural patterns and processes     | Properties derived from natural features and processes                    | 5                     | 3    |
| Colour and light                   | Colour, light, and material qualities and space relationships with nature  | 53                    | 32   |
| Place-based relationships          | Culture together with ecology, rooted in geography                        | 46                    | 27   |
| Human-nature relationship          | Paired biological needs with nature                                        | 4                     | 2    |

Table 7
Comparison table ranking highest to lowest frequency of attributes identified in the literature and by practitioners

| Biophilic aspect | Research | Practitioners |
|------------------|----------|---------------|
| Colour           | Engagement (2) | Natural materials (6) |
|                  |           | Geographic connection to place (5) |
|                  |           | Composition (4) |
| Light            | Engagement (5) | Natural light (9) |
|                  | Natural light (4) | Natural materials (6) |
|                  | Preference (3)  | Engagement (4) |
|                  | Pragmatics (2)  | Geographic connection to place (4) |
|                  |            | Pragmatics (4) |
|                  |            | Ecological connection to place (3) |
|                  |            | Fluid forms (3) |
|                  |            | Abstraction of nature (2) |
|                  |            | Integration of culture and ecology (2) |
|                  |            | Curves and arches (2) |
|                  |            | Filtered light (2) |
| Materiality      | Plants (4) | Natural materials (7) |
|                  | Abstraction of nature (2) | Geographic connection to place (6) |
|                  | Natural materials (2) | Ecological connection to place (6) |
|                  | Preference (2) | Abstraction of nature (4) |
|                  | Views and vistas (2) | Botanical motifs (4) |
|                  |            | Cultural connection to place (4) |
|                  |            | Animal-like (3) |
|                  |            | Communication (3) |
|                  |            | Curves and arches (3) |
|                  |            | Engagement (3) |
|                  |            | Fluid forms (3) |
|                  |            | Integration of culture and ecology (3) |
|                  |            | Pragmatics (3) |
|                  |            | Shells and spirals (3) |
|                  |            | Sensory richness (3) |
|                  |            | Composition (2) |
|                  |            | Plants (2) |

*Note: Frequencies noted in parenthesis, features including more than one reference were included*
Colour, Light, and Materiality in Biophilic Design Application and Evidence

The application and evidence of biophilic design within colour, light, and materiality varied between each other. The similarities and differences between research and practice can be seen in Table 7. This finding highlights that researchers and designers may have had divergent agendas; however, some similarities still exist. The top attributes in the table that were shared by both the literature review and practitioners were abstraction of nature, engagement, natural light, natural materials, and views and vistas.

Colour as a biophilic design feature

The colour literature was not a large contributor to this review, although there has been a great deal of research conducted on colour. Colour was not well identified here, connecting it to nature-based attributes. To summarise, the number of articles with multiple sources per BID-M features for colour were engagement (2) and abstraction of nature, composition, and preference (1 each), while the number of attributes designers used varied from the research findings, including natural materials (6), geographic connection to place (5), and composition, engagement, and ecological connection to place (4). Colour had the weakest representation in the literature with only four of 19 articles and a weak to moderate biophilic implication strength. The engagement was the most commonly researched biophilic feature related to colour.

Looking for direct linkages between colour and health outcomes is still under-researched, and “no sufficient evidence exists in the literature to the causal relationship between settings painted in particular colors and patients’ healthcare outcomes” (Tofle et al., 2004, p. 4). Colour can influence behaviour and cognition based on the context, for example, aiding wayfinding (Dalke et al., 2006; Wise & Wise, 1988). The colour spectrum of light has been directly linked to circadian rhythms and human response with health outcomes (Bosch et al., 2012), so there is evidence growing around how colour influences people and may be influenced by a person’s stimulus screening ability. A study in an office setting found that people with low stimulus screening reported more dysphoria in red and white offices than their counterparts, high-screeners, who performed better on tasks in red offices and poorer in blue-green offices (Kwallek et al., 1997). One of the reviewed studies found that coloured lighting affected responses in an experiment looking at red, green, and white lighting (Odabaşioğlu & Olguntürk, 2015). This finding is similar to other research that found “demonstrable perceptual impressions of
color applications that can affect the experience and performance of people in particular environments" (Tofle et al., 2004, p. 4), such as perceptions of spaciousness and confinement attributed to a colour value. Additionally, warm colours can promote memory recall which could be helpful for wayfinding (Hidayetoglu et al., 2012). While the research has been focused more on human engagement with colour, practitioners have been providing clients with considerations for colour by using local nature-based cues for materials in their design compositions.

**Lighting as a biophilic design feature**

The research on lighting spanned from weak to strong within ten articles. Lighting research focused on *engagement* (5), *natural light* (4), *preference* (3), and *pragmatics* (2). Practitioners' most frequently cited use of light was represented in the biophilic attributes *natural light* (9), *natural materials* (6), *pragmatics* (4), and *engagement, geographic connection to place*, and *pragmatics* (4). As stated above, colour and daylight have been studied regarding human health and performance. These generally fall into four mechanisms: 1) enabling the performance of visual tasks, 2) controlling the body’s circadian system, 3) affecting mood and perception, and 4) facilitating direct absorption for critical chemical reactions within the body (Olguntürk & Demirkan, 2011).

The study of Sanati and Utzinger (2013) involved a variety of biophilic features, such as *filtered light, natural light, preference, engagement, pragmatics, and mastery/control*. Their main topic was using a light shelf (*natural and filtered light*) to help reduce the need for lowering blinds, which led to lesser view occlusion and enabled task performance. It also showed significant energy savings which is a good example of *pragmatics*. The research focused on humans interacting with and their preference for lighting, including natural light, which was slightly different from the practitioner's light application. The study participants generally sought to use natural light, specifically light for practical purposes, and to connect to the local geography.

**Materiality as a biophilic design feature**

The most obvious and well-known strategy for including biophilia inside is the incorporation of *plants* (4) and was followed by *abstraction of nature, natural materials, preference, and views and vistas* (2 each). Materiality in practice included *natural materials* (7), *geographic connection to place and ecological connection to place* (6), and *abstraction of nature, botanical motifs and cultural connection to place* (4). Along with natural light and views, as already discussed, plants are perhaps one of the most impactful biophilic attributes that can improve
perceptions of well-being (Dijkstra et al., 2008; Gray & Birrell, 2014; Park & Mattson, 2009; Raanaas et al., 2010). Gray and Birrell (2014) conducted a study with the integration of plants into a workplace and found short-term positive effects, but several other adjustments made the space different from previous offices, limiting applicability. A study of hospital patients exposed to rooms with plants showed reduced feelings of stress through the mediating variable of attractiveness (Dijkstra et al., 2008). A similar integration of plants in a hospital room setting with surgery patients found that having plants in the rooms during recovery had a positive influence on health outcomes compared to the control group (Park & Mattson, 2009).

These findings are not unexpected within the biophilia theory, with plants offering an actual natural connection that is direct and more impactful than representations. Representation of plants, or botanical motifs, have also been studied in nature-themed artwork and was the preference of children given art choices (Eisen et al., 2008). Combining direct and indirect connections to nature with plants and visual imagery into an office space was tested with students and the aesthetic quality reduced perceived stress (Campbell, 1979). Even views of natural environments or the use of natural materials can be influential (McCoy & Evans, 2002). McCoy and Evan’s study (2002) specifically looked at creativity and found that “environments perceived low in creativity potential were consistently windowless, finished in manufactured or composite materials, and with overall cool colors” (p. 420). The research has been looking at plants, images and preferences of users, while the designers have been using biophilic materials through the use of natural materials and selecting materials to connect the design to the local geography and ecological systems.

**Conclusion**

The designer’s selection of colour was a key component that thoughtfully incorporates local environmental colours. Elliot and Maier’s recent colour literature review also showed that colour has an “important influence on people’s affect, cognition, and behavior” (Elliot & Maier, 2014, p. 112). These are key considerations when trying to create a connection to nature, while also being fully controlled by the designer through the selection of hue, saturation, and value within the overall design concept (Portillo, 2009). Engagement was more prevalent in research, while natural materials were used for natural colour integration more often by practitioners. This difference could highlight research interests in the behavioural side of design, while design application has been utilising common-sense approaches to connect with nature by bringing in items directly from nature. This is
perhaps linked to perceptions by the designer for fulfilling the client’s innate needs.

Regarding light, the importance of lighting design can be seen as a fundamental requirement for an interior environment. Engagement with light was, similarly to colour, the most common research topic. However, natural light was the most common design application. Natural light is again a very well-known important natural element. Natural light, fresh air, and views have been coming back into prominence in research and application since Florence Nightingale proposed its use in hospitals for their healing qualities (Nightingale et al., 1994). The attribute pragmatics had a shared common strategy among researchers and designers. This was found in consideration for natural light and limiting glare. Strategies such as daylight tubes could help with both, as found in one of the identified studies (Almusaed & Almssad, 2014). Light in interior design research focused on biological studies of natural light. This was similarly found by Gillis and Gatersleben (2015) in their review of psychological literature on the health and well-being benefits of biophilic design.

Looking at materiality findings, research was dominated by studies that looked at the benefits of plants and abstract nature images. Practitioners relied instead on natural materials; however, Gillis and Gatersleben (2015) found specifically that natural materials had limited psychological research attention. Natural materials are a common-sense way of creating a biophilic feeling within a space. However, a study of natural materials found that preference varied for the number of natural materials and that variety is needed (Nyrud et al., 2014). This is supported in the theory of biophilia, where incorporation of various natural features should support connections to nature while people may still exhibit individual preferences. The ability for designers to use natural materials and connect to the local environment through material selection could benefit from additional research. The reliance on the material uses in practice could also be due to a lack of familiarity with the variety of other options in biophilic interior design.

In comparison, it is interesting to see that research had more of an emphasis on plants. This topic may be easier to research with targeted ways to control variables, explaining their prevalence and diverse fields devoted to their study. Additionally, this may be outside some interior designers’ scope of work. A review of the psychological benefits of indoor plants among 21 studies found heterogeneity in the results, which limits general beneficial claims (Bringslimark et al., 2009), so more research is still warranted. For example, infection
control is a key consideration for plant inclusion in healthcare settings, but current guidelines have found that with simple control protocols “flowers and potted plants need not be restricted from areas for immunocompetent patients” (Center for Disease Control, 2003, p. 149). Concerns for infection, litigation, and maintenance, however, may be holding back increased indoor plant use.

Colour, light, and materiality are complex and have been studied across many disciplines. A larger, targeted systematic review of each feature may be helpful to draw additional research together for designers concerning the three concepts and among all the attributes. This review, although very limited and targeted, has been an important starting point for attempting to explore the current state of biophilic design research and practice. Additional research among the biophilic attributes can guide designers in applying evidence-based design.

The designers used many studies and strategies related to more than one category of colour, light, and materiality. These are somewhat inextricable concepts. In fact, it is probably when all three of these concepts are thoughtfully used together that truly biophilic designs are created. It was found that interior designers used these three tools to fulfill their project goals and biophilic design. The many biophilic design attributes afford additional opportunities for designers to try new approaches and for additional research to offer further guidance. More varied incorporation of nature may allow designers to apply their creative ability in exciting new ways that can be studied and shared in the future.

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