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

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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

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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	Curiousity/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.

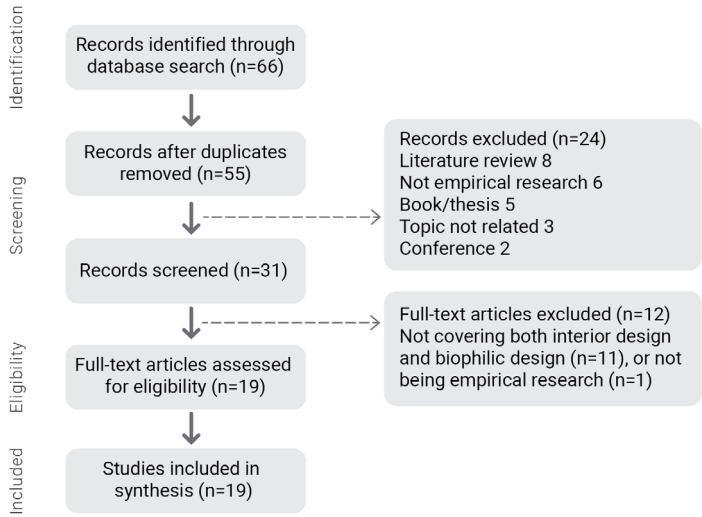

Figure 1
Literature review diagram
(Image by authors based on PRISMA (Moher et al., 2009))

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).

Table 2
Demographics of respondents

Practice years	n	%	Certification[b]	n	%	Specialisation[b]	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[a]	2	8.7	Other	6	25.8
≥26	7	30.4	-	-	-	-	-	-

Note: [a]Other included CSSBB and EBD as well as 1st class Korean Architecture Engineer; [b]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.

Table 3
Literature review biophilic design results

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 (2008)	Preference, botanical motifs			v	+++	Nature representation in artwork for children's spaces are most preferred, choices should be available
Gray & Birrell (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		++	CQAT 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
Odabaşioğlu & Olguntürk (2015)	Composition, engagement	v	v		++	Coloured lighting affected perceptions
Olguntürk & Demirkan (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

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).

Table 4
Biophilic feature frequency in the literature review

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.

Table 5
Biophilic feature frequency in practice

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).

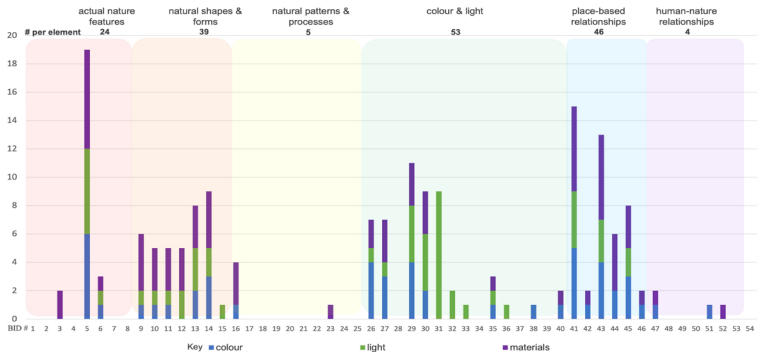

Figure 2
Frequency of practitioner comments regarding their inclusion of biophilia by BID-M attributes and elements
(Image by authors)

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 characterstics 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	Practicioners
Colour	Engagement (2)	Natural materials (6) Geographic connection to place (5) Composition (4) Ecological connecition to place (4) Engagement (4) Abstraction of nature (3) Communication (3) Integration of culture and ecology (3) Fluid forms (2) Pragmatics (2) Cultural connection to place (2)
Light	Engagement (5) Natural light (4) Preference (3) Pragmatics (2)	Natural light (9) Natural materials (6) Engagement (4) 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) Abstraction of nature (2) Natural materials (2) Preference (2) Views and vistas (2)	Natural materials (7) Geographic connection to place (6) Ecological connection to place (6) Abstraction of nature (4) Botanical motifs (4) Cultural connection to place (4) Animal-like (3) Commmuncation (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 fulfil 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.

References

Abkar, M., Kamal, M., Maulan, S., & Mariapan, M. (2010). Influences of viewing nature through windows. *Australian Journal of Basic and Applied Sciences, 4*(10), 5346–5351.

Alimoglu, M., & Donmez, L. (2005). Daylight exposure and the other predictors of burnout among nurses in a university hospital. *International Journal of Nursing Studies, 42*(5), 549–555. https://doi.org/10.1016/j.ijnurstu.2004.09.001

Almusaed, A., & Almssad, A. (2014). Natural lighting efficiency by means of sun-skylight-tubes. *International Journal of Engineering and Advanced Technology, 3*(3), 16–20.

Beute, F., & Kort, Y. A. W. (2014). Salutogenic effects of the environment: Review of health protective effects of nature and daylight.

Applied Psychology: Health and Well-Being, 6(1), 67–95. https://doi.org/10.1111/aphw.12019

Blumberg, R., & Devlin, A. S. (2006). Design issues in hospitals. *Environment and Behavior, 38*(3), 293–371. https://doi.org/10.1177/0013916505281575

Bosch, S., Bledsoe, T., & Jenzarli, A. (2012). Staff perceptions before and after adding single-family rooms in the NICU. *Health Environments Research & Design, 5*(4), 64–75. https://doi.org/10.1177/193758671200500406

Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology, 29*(4), 422–433. https://doi.org/10.1016/j.jenvp.2009.05.001

Campbell, D. E. (1979). Interior office design and visitor response. *Journal of Applied Psychology, 64*(6), 648–653. https://doi.org/10.1037/0021-9010.64.6.648

Carabelli, G. (2020, October 19). House plants were our link with nature in lockdown—now they could change how we relate to the natural world. *The Conversation*. https://theconversation.com/house-plants-were-our-link-with-nature-in-lockdown-now-they-could-change-how-we-relate-to-the-natural-world-147637

Center for Disease Control. (2003). *Guidelines for environmental infection control in health-care facilities*. https://www.cdc.gov/infectioncontrol/guidelines/environmental/index.html

Daneshgarmoghaddam, G., & Bahrainy, H. (2014). The role of architecture-nature interaction in the quality of place attachment, case study: House-gardens in Hamedan, Iran. *Armanshahr Architecture & Urban Development, 12*, 107–117.

Dalke, H., Little, J., Niemann, E., Camgoz, N., Steadman, G., Hill, S., & Stott, L. (2006). Colour and lighting in hospital design. *Optics & Laser Technology, 38*(4–6), 343–365. https://doi.org/10.1016/j.optlastec.2005.06.040

Derr, V., & Kellert, S. (2013). Making children's environments "R.E.D.": Restorative environmental design and its relationship to sustainable design. *EDRA44: Healthy + Healing Places*. Providence, RI.

Dijkstra, K., Pieterse, M. E., & Pruyn, A. (2008). Stress-reducing effects of indoor plants in the built healthcare environment: The

mediating role of perceived attractiveness. *Preventive Medicine, 47*(3), 279–283. https://doi.org/10.1016/j.ypmed.2008.01.013

Dittmar, M. (2001). Changing colour preferences with ageing: A comparative study on younger and older native Germans aged 19-90 years. *Gerontology, 47*(4), 219–226. https://doi.org/10.1159/000052802

Eisen, S. L., Ulrich, R. S., Shepley, M. M., Varni, J. W., & Sherman, S. (2008). The stress-reducing effects of art in pediatric health care: Art preferences of healthy children and hospitalized children. *Journal of Child Health Care, 12*(3), 173–190. https://doi.org/10.1177/1367493508092507

Elliot, A. J., & Maier, M. A. (2014). Color psychology: Effects of perceiving color on psychological functioning in humans. *Annual Review of Psychology, 65*(1), 95–120. https://doi.org/10.1146/annurev-psych-010213-115035

Gesimondo, N., & Postell, J. C. (2011). *Materiality and interior construction*. John Wiley.

Gillis, K., & Gatersleben, B. (2015). A review of psychological literature on the health and wellbeing benefits of biophilic design. *Buildings, 5*(3), 948–963. https://doi.org/10.3390/buildings5030948

Gray, T., & Birrell, C. (2014). Are biophilic-designed site office buildings linked to health benefits and high performing occupants? *International Journal of Environmental Research and Public Health, 11*(12), 12204–12222. https://doi.org/10.3390/ijerph111212204

Greene, J., Caracelli, V., & Graham, W. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis, 11*(3), 255–274. https://doi.org/10.3102/01623737011003255

Hidayetoglu, M. L., Yildirim, K., & Akalin, A. (2012). The effects of color and light on indoor wayfinding and the evaluation of the perceived environment. *Journal of Environmental Psychology, 32*(1), 50–58. https://doi.org/10.1016/j.jenvp.2011.09.001

Kahn, P., & Kellert, S. (Eds.). (2002). *Children and nature: Psychological, sociocultural, and evolutionary investigations*. MIT Press.

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press.

Kellert, S. (1993). The biological basis for human values of nature. In E. Wilson & S. Kellert (Eds.), *The biophilia hypothesis* (pp. 42–69). Island Press.

Kellert, S. (2008). Dimensions, elements, and attributes of biophilic design. In S. Kellert, J. Heerwagen, & M. Mador (Eds.), *Biophilic design: The theory, science, and practice of bringing buildings to life* (pp. 3–19). Wiley.

Kellert, S., Heerwagen, J., & Mador, M. (Eds.). (2008). B*iophilic design: The theory, science and practice of bringing buildings to life*. Wiley.

Kim, I. T., Choi, A. S., & Sung, M. K. (2017). Development of a colour quality assessment tool for indoor luminous environments affecting the circadian rhythm of occupants. *Building and Environment, 126*, 252–265. https://doi.org/10.1016/j.buildenv.2017.10.009

Kilmer, R., & Kilmer, W. O. (2014). *Designing interiors* (2nd ed.). John Wiley and Sons.

Kjellgren, A., & Buhrkall, H. (2010). A comparison of the restorative effect of a natural environment with that of a simulated natural environment. *Journal of Environmental Psychology, 30*(4), 464–472. https://doi.org/10.1016/j.jenvp.2010.01.011

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., Behar, J. V., Hern, S. C., & Engelmann, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology, 11*(3), 231–252. https://doi.org/10.1038/sj.jea.7500165

Koranteng, C., & Simons, B. (2012). An evaluation of natural lighting levels in students' hostels in a suburb of Kumasi, Ghana. *Advances in Applied Science Research, 3*(1), 548–554.

Korpela, K., Borodulin, K., Neuvonen, M., Paronen, O., & Tyrväinen, L. (2014). Analyzing the mediators between nature-based outdoor recreation and emotional well-being. *Journal of Environmental Psychology, 37*, 1–7. https://doi.org/10.1016/j.jenvp.2013.11.003

Kwallek, N., Woodson, H., Lewis, C. M., & Sales, C. (1997). Impact of three interior color schemes on worker mood and performance relative to individual environmental sensitivity. *Color Research & Application, 22*(2), 121–132. https://doi.org/10.1002/(SICI)1520-6378(199704)22:2<121::AID-COL7>3.0.CO;2-V

McGee, B., Park, N., Portillo, M., Bosch, S., & Swisher, M. (2019). DIY biophilia: Development of the Biophilic Interior Design Matrix as a design tool. *Journal of Interior Design, 44*(4), 201–221. https://doi.org/10.1111/joid.12159

Merriam-Webster. (2021). *Color.* https://www.merriam-webster.com/dictionary/color

Merriam-Webster. (2021). *Light*. https://www.merriam-webster.com/dictionary/light

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med, 6*(7), e1000097. https://doi.org/10.1371/journal.pmed1000097

Livingston, J. (2014). *Designing with light: The art, science and practice of architectural lighting design*. Wiley.

Louv, R. (2011). *The nature principle: Human restoration and the end of nature-deficit disorder.* Algonquin Books of Chapel Hill.

McCoy, J. M., & Evans, G. W. (2002). The potential role of the physical environment in fostering creativity. *Creativity Research Journal, 14*(3–4), 409–426. https://doi.org/10.1207/S15326934CRJ1434_11

Nanda, U., Zhu, X., & Jansen, B. H. (2012). Image and Emotion: From Outcomes to Brain Behavior. *HERD: Health Environments Research & Design Journal, 5*(4), 40–59. https://doi.org/10.1177/193758671200500404

Nightingale, F., Calabria, M. D., & Macrae, J. (1994). *Suggestions for thought*. University of Pennsylvania Press.

Nyrud, A. Q., Bringslimark, T., & Bysheim, K. (2014). Benefits from wood interior in a hospital room: A preference study. *Architectural Science Review, 57*(2), 125–131. https://doi.org/10.1080/00038628.2013.816933

Odabaşioğlu, S., & Olguntürk, N. (2015). Effects of coloured lighting on the perception of interior spaces. *Perceptual & Motor Skills, 120*(1), 183–201. https://doi.org/10.2466/24.PMS.120v10x4

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B, 19*(7), 305–343. https://doi.org/10.1080/10937404.2016.1196155

Olguntürk, N., & Demirkan, H. (2011). Colour and design: From natural patterns to monochrome compositions. *Optics & Laser Technology, 43*(2), 270–281. https://doi.org/10.1016/j.optlastec.2009.06.014

Orr, D. W. (1993). Love it or lose it: The coming biophilia revolution. In S. R. Kellert & E. O. Wilson (Eds.), *The biophilia hypothesis* (pp. 415–440). Island Press.

Park, N.-K., & Farr, C. A. (2007a). Retail store lighting for elderly consumers: An experimental approach. *Family and Consumer Sciences Research Journal, 35*(4), 316–337. https://doi.org/10.1177/1077727X07300096

Park, N.-K., & Farr, C. A. (2007b). The effects of lighting on consumers' emotions and behavioral intentions in a retail environment: A cross-cultural comparison. *Journal of Interior Design, 33*(1), 17–32. https://doi.org/10.1111/j.1939-1668.2007.tb00419.x

Park, S. -H., & Mattson, R. H. (2009). Ornamental indoor plants in hospital rooms enhanced health outcomes of patients recovering from surgery. *The Journal of Alternative and Complementary Medicine, 15*(9), 975–980. https://doi.org/10.1089/acm.2009.0075

Pati, D., Freier, P., O'Boyle, M., Amor, C., & Valipoor, S. (2016). The impact of simulated nature on patient outcomes: A study of photographic sky compositions. *HERD: Health Environments Research & Design Journal, 9*(2), 36–51. https://doi.org/10.1177/1937586715595505

Pilotti, M., Klein, E., Golem, D., Piepenbrink, E., & Kaplan, K. (2015). Is viewing a nature video after work restorative? Effects on blood pressure, task performance, and long-term memory. *Environment and Behavior, 47*(9), 947–969. https://doi.org/10.1177/0013916514533187

Portillo, M. (2009). *Color planning for interiors: An integrated approach to designed spaces*. Wiley.

Raanaas, R. K., Evensen, K. H., Rich, D., Sjøstrøm, G., & Patil, G. (2011). Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology, 31*(1), 99–105. https://doi.org/10.1016/j.jenvp.2010.11.005

Raanaas, R. K., Patil, G. G., & Hartig, T. (2010). Effects of an indoor foliage plant intervention on patient well-being during a residential rehabilitation program. *HortScience, 45*(3), 387–392. https://doi.org/10.21273/HORTSCI.45.3.387

Rossin, K. J. (2010). *Biomimicry: Nature's design process versus the designer's process*. 559–570. https://doi.org/10.2495/DN100501

Sanati, L., & Utzinger, M. (2013). The effect of window shading design on occupant use of blinds and electric lighting. *Building and Environment, 64*, 67–76. https://doi.org/10.1016/j.buildenv.2013.02.013

Tavsan, F., & Sonmez, E. (2015). Biomimicry in furniture design. *Procedia: Social and Behavioral Sciences, 197*, 2285–2292. https://doi.org/10.1016/j.sbspro.2015.07.255

Theodorson, J. (2018). North v. south: The impact of orientation in daylighting school classrooms. *SOLAR 2008: Catch the Clean Energy Wave*. https://www.academia.edu/8568609/North_V._South_The_Impact_of_Orientation_in_Daylighting_School_Classrooms

Tofle, R. B., Schwarz, B., Yoon, S.-Y., Max-Royale, A., & Des, M. E. (2004). Color in healthcare environments: A research report. *Coalition for Health Environments Research*. https://www.healthdesign.org/sites/default/files/color_in_hc_environ.pdf

Totaforti, S. (2018). Applying the benefits of biophilic theory to hospital design. *City, Territory and Architecture, 5*(1). https://doi.org/10.1186/s40410-018-0077-5

Ulrich, R. (1992). How design impacts wellness. *The Healthcare Forum Journal, 35*(5), 20–25.

Vouchilas, G., & Ulasewicz, C. (2017). Millennial exploration of good design: Perceptions of the elements of design through images and language. *The International Journal of the Image, 8*(4), 39–50. https://doi.org/10.18848/2154-8560/CGP/v08i04/39-50

Wilson, E. O. (1984). *Biophilia: The human bond with other species*. Harvard University Press.

Wise, B. K., & Wise, J. A. (1988). The human factors of color in environmental design: A critical review. *NASA*. https://ntrs.nasa.gov/citations/19890006161

Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., & Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment, 132*, 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006