ITU A|Z • Vol 19 No 2 • July 2022 • 353-369

Biophilic dimensions of products and their effects on user preferences

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Received: May 2021 • Final Acceptance: February 2022

Abstract

Biophilia is hypothesized as one of the defining concepts guiding human preferences of everyday life. Although "biophilia" has been well integrated as a design approach in Architectural and Urban Design, it is yet to develop in industrial design. Employing a two-staged approach, we aimed to define the biophilic characteristics of a product multidimensionally and examine their effects on the users' preferences.

The first stage consisted of empirical studies to describe the biophilic dimensions. This endeavor yielded a word set (N=78) that qualifies the biophilic dimensions (N=6). The words obtained consisted of biophilic design values and the hypothetical biophilic product dimensions that were proposed by researchers. Also, we obtained a set of product images (N=18) to be used throughout the study.

The second stage was designed to explore the effects of biophilia on user preferences. An expert group (N=120) assessed the associations between the words and product sets. Also, a user group (N=1.206) rated how much they preferred these products. The data obtained from the experts and the users were analyzed to examine how the biophilic dimensions predicted the user preferences by regression analyses conducted on SPSS 27. The results revealed that the functional dimension has a significant effect on user preferences in both biophilic and non-biophilic/biophobic cases while the psychological dimension has a significantly negative effect on user preferences just in non-biophilic/biophobic cases.

Keywords

Biophilia, Biophilic design, Biophilic dimensions of products, User product preferences, Industrial design.

doi: 10.5505/itujfa.2022.76892

1. Introduction

For industrial designers, it is often imperative to understand the effects of products on user preferences and the underlying psychological mechanisms. The biophilic quality of a product may be proposedly one of the qualities that can affect the users' decision mechanism. It is fair to say that it is virtually impossible to understand the effects of the biophilic quality of products on user preferences without defining their biophilic characteristics. However, to the best of our knowledge, there is neither an empirical effort to define the biophilic characters of products nor their effects on the user preferences up to date. Therefore, the questions addressed in this study were "What are the dimensions of a product that characterize its biophilic quality?", and "How do the biophilic dimensions of products affect user preferences?"

Although the concept of biophilia sometimes evokes a psychological disorder (e.g. opposite of necrophilia), as Wilson (1984) stated, biophilia in the most general sense refers to a healthy state in that it corresponds to an innate love of life and nature. Biophilia is a phenomenon that innately acts on the physiological and psychological well-being of humans. A body of studies shows that interaction with nature has a significant role in decreasing blood pressure, illness symptoms, and stress-related disorders (Kellert & Calabrese, 2015). Taking a walk through woods or watching across the sea-side, even to look at a depiction of a natural view, have positive effects on human well-being (Kellert, 2005). Nature dependency is wired in our brain and body (Heerwagen & Hase, 2001) and that essential yet implicit phenomenon, biophilia, is worth calling forth to dig its effects and benefits up in a more detailed way. Yet biophilia is also an essential factor in people's decision mechanism regarding spatial preferences in particular, as the evolutionary hypotheses of sheltering predict.

From the perspective of biophilia, the interaction of humans with the environment and how this interaction reflects on people's life choices have long attracted the attention of researchers. In the fields of Architecture and Urban Planning, biophilic designs often reflect the history of people's interactions with their physical environment. Jay Appleton (1975) proposed Prospect & Refuge Theory as a need to hide from dangers in a proper location where one can observe the possible attack. In his seminal Savanna Hypothesis, ecologist Gordon Orians (1980) argued that our current preferences for the environment were inherited from our ancestors, which led us to explore vital resources but avoid hazards. He maintained that as a species that had evolved in a natural, even wild environment, humans are still searching for those natural features in their modern environment. Orians and psychologist Judith Heergaven (1992) expanded it by proposing the Habitat Selection Hypothesis predicting that the tendencies to the tropic African savanna-like features such as the trees and canopies providing open views and hidden positions from dangers, landscapes rich in food resources, hunting possibilities, and water resources, and also the complexity of the intriguingly rich spaces, yet not too complicated are still influential on the modern life preferences of humans (Orians & Heerwagen, 1992).

Biophilic preferences are therefore functional, and selection has likely fashioned preferences of ancestral humans in favor of assessment of biophilic features more positively. Consistent with this analysis, proposed by Rachel and Stephen Kaplan (1989), the Attention Restoration Theory stated that nature's complex and ordered structure passively caught the human's attention. In other words, our attentional system has evolved to be sensitive to biophilic features which are presumably adaptive for survival and reproduction. Thus, the theory provided an implicit but strong connection between the human mind and nature (Kaplan & Kaplan, 1989).

Probably, fractality is the most essential physical structure of nature and life. As Salingaros (2015) asserted, natural entities have a complex fractal structure rather than simply linear, perpendicular, or planar one, and humans as entities constituted by fractal structure themselves, are prone to detect and bond with the natural fractals.

Many modern human-built structures that lack fractal organization, or are non-biophilic, have no competency either to have a healthy relationship with humans or to engage their attention (Salingaros, 2015; Salingaros & Masden II, 2008).

Ostensibly, all theories above also include avoiding the hazards of the natural environment, which is called "biophobia". Kellert (1997) articulated biophobia as "Human fascination for natural diversity is a two-edged sword-one side enriching and inspiring; the other, the source of great dread and disdain.". He also emphasized its evolutionary significance for survival, and the guiding role in avoiding the ominous sides of nature, which could cause dangerous consequences (Kellert, 1993). The dangers in nature require substantial attention and energy.

Another related concept, 'non-biophilia', expresses the non-presence of nature besides the dichotomy of biophilia and biophobia (Gochman, n.d.). Gochman, (n.d.) describes the non-biophilic sites as "loud, smoky, barren, or non-restorative" in the scale of the city. Non-biophilia is also the opposite of biophilia, but it doesn't belong to nature or the biological world as biophobia does. It may indicate the human-built things which do not even recall the natural or biophilic principles.

Although they hold different perspectives in their theoretical analyses, all theorists agree on the restorative effects of nature on people's physical and mental health. Exposure to nature improves well-being by reducing stress, blood pressure, muscle tension, heart rate, and anxiety, and by increasing dopamine levels, immune functions, attentional vigilance, sense of serenity, mood, and physical and mental performance. (*See also* Arvay, 2015/2018; Browning et al., 2014; Kaplan & Kaplan, 1998; Kellert, 2005, 2008; Kellert & Calabrese, 2015; Ryan et al., 2014; Salingaros, 2015; Salingaros & Masden II, 2008; Ulrich, 2008; Wilson, 2008).

In cases, humans have no direct contact with nature (e.g. hiking or camping in the forest, swimming in the sea), we can still speak of biophilia as indirect contact (e.g. potted plant, manicured lawn) and symbolic contact (e.g. visual depictions in paintings and photographs, nature metaphors in stories and myths) (Kellert, 2005); and the restorative effects of the indirect and symbolic contacts with nature as well (Ulrich, 2008).

Biophilic design seeks the essence of the natural features which are beneficial for humans. Consequently, the biophilic approach in the built environment is of prime concern considering the lack of natural attributes of today's environment. Joye (2007) argued that the restorative effects of nature might have originated in the fractal structure and patterns that all-natural entities have rather than natural scenery. He emphasized the importance of considering the biophilic approach as a multidisciplinary study, including the psychological and cultural aspects together with the fractal structure (Joye, 2007). Indeed, the convergence of physical and social elements is one of the most prominent topics in the literature on biophilia.

An increase in the awareness of the discovered effects of biophilia on personal well-being and the need for more natural features in the artificial environment led the designers to create spaces with direct natural items or features referring to savanna. Besides the human-centered and restorative approach of biophilic design, as Ryan stated in the introduction of Salingaros's (2015) work, biophilic features are used to design places like offices, schools, healthcare facilities, airports, manufacturing facilities to improve efficiency. Similarly, Heerwagen (2003) pointed out that people tended to go to the shopping malls or department stores more where the retail settings are manipulated by employing savanna-like features. Even though the examples above illustrate the commercial use of biophilic features and are out of the scope of this research, it is significant to see the impact of the biophilic approach.

A body of work has been done in biophilic architecture and urban design to specify the basics, categories, and qualities. Architectural and urban design often employs biophilic approaches regarding direct spatial relation with the concept of biophilia. However, product

design remains out of the literature on biophilia even though the products are significant parts of the built environment. This paper is based on research to frame the product-specific biophilic dimensions to develop a definition for biophilic products and search for the effects of those dimensions on users' product preferences.

2. Method

The cognitive representations of products are important for individuals concerning the adaptations to their environment. On the other hand, those cognitive representations occur through a set of dimensions that categorize the product qualities rather than as an arbitrary criterion. The sets of product value are mostly proposed based on an intersection of physical and social dimensions (Boztepe, 2007; Frondizi, 1971; Holbrook, 1999) more or less as Boradkar (2010) suggested "symbolic, emotional, historical, cultural, aesthetic, social, political, environmental, utilitarian, economic, and brand value". To obtain a comprehensive list, we employed both physical and social categories spanning seven dimensions including form, function, material, sensorial, attitude, semantic, and psychological dimensions. Those dimensions are often taken as criteria when the potential to reflect a biophilic character in the field of design is evaluated. Within this research, the economic dimension is excluded due to focusing on preferences of use rather than affordability. Since there is no definition of product-specific biophilic characteristics in literature; starting with common dimensions enabling a deeper and detailed approach would provide a multidimensional perspective to the study rather than a binary evaluation like tagging a product as biophilic or not. The hypothetical definition of a biophilic product with its common dimensions and possible qualities is demonstrated in Table 1.

The research consists of two stages. The first stage aims to define the biophilic product among its dimensions, and the second stage searches for the effects of those biophilic dimensions on users' product preferences. The first stage covers a set of empirical studies that are 1st and 2nd user group studies, and 1st and 2nd expert group studies, to define the dimensions of a biophilic product. The second stage includes the 3rd expert and user group studies, reliability tests, and linear multiple regression analysis to understand the user preferences regarding the biophilic dimensions.

Table 1. *Biophilic product dimensions and proposed qualities as a basis.*

	form	function	material	sensory
Physical dimensions	(a)symmetry	energy saving	healthy	color
	curve	productivity	natural	odor
	contrast	comfort	safe	sound
	fractal geometry	ergonomy		taste
	rhythm			texture
	clear vision			vibration
	coherency with the function			
	balance			
	organic / amorphous			

	attitude	psychological	semantic
Social dimensions	active	consistency	connotations
	ecological	emotions	iconic value
	familiarity	feelings	symbolic value
	healthy	safety	historical / story
	honesty	wellbeing	
	loyalty (domestication)	calmness	
	identifiability		
	integrating the user		
	coherency (environment relationship)		

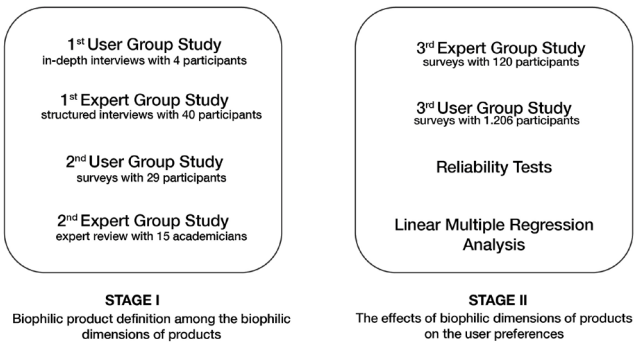

Figure 1. *Method scheme.*

2.1. Stage I: Biophilic product definition among the biophilic dimensions of products

In stage I, the research is designed to define the biophilic product with its dimensions to be used for the user preferences search. First, in-depth interviews were held with 4 participants (1st user group) as a pilot study to determine the product images that would

Table 2. *Elements and attributes of biophilic design (Kellert, 2008, p.15).*

Elements and Attributes of Biophilic Design					
Environmental features	**Natural shapes and forms**	**Natural patterns and processes**	**Light and space**	**Place-based relationships**	**Evolved human-nature relationships**
Color	Botanical motifs	Sensory variability	Natural light	Geographic connection to place	Prospect and refuge
Water	Tree and columnar supports	Information richness	Filtered and diffused light	Historic connection to place	Order and complexity
Air	Animals (mainly vertebrate) motifs	Age, change and the patina of time	Light and shadow	Ecological connection to place	Curiosity and enticement
Sunlight	Shells and spirals	Growth and efflorescence	Reflected light	Cultural connection to place	Change and metamorphosis
Plants	Egg, oval and tubular forms	Central focal point	Light pools	Indigenous materials	Security and protection
Animals	Arches, vaults, domes	Patterned wholes	Warm light	Landscape orientation	Mastery and control
Natural materials	Shapes resisting straight lines and right angles	Bounded spaces	Light as shape and from	Landscape features that define building form	Affection and attachment
Views and vistas	Simulation of natural features	Transitional spaces	Spaciousness	Landscape ecology	Attraction and beauty
Façade greening	Biomorphy	Linked series and chains	Spatial variability	Integration of culture and ecology	Exploration and discovery
Geology and landscape	Geomorphology	Integration of parts to wholes	Space as shape and form	Spirit of place	Information and cognition
Habitats and ecosystems	Biomimicry	Complementary contrasts	Spatial harmony	Avoiding placelessness	Fear and awe
Fire		Dynamic balance and tension	Inside-outside spaces		Reverence and spirituality
		Fractals			
		Hierarchically organized ratios and scales			

be used during the research and to structure the interviews with the user groups. In this pilot study, over 200 product images were displayed to the users on a monitor and after the first view, they were asked to review the images considering the following criteria:

- familiarity,
- convenience to be recognized regarding the form and function,
- use frequency in daily life.

A set of product images consisting of 95 products were chosen by the criteria that the participants put above and balanced by the researcher by considering the following:

- having physical or abstract references to living or natural beings,
- being made of natural or artificial materials,
- connotation to status and prestige,
- same/similar products demonstrated in different backgrounds (natural or artificial surroundings),
- same kind of products used in different contexts (different shooting angles or set-ups),
- same or similar products with different colors and patterns,
- Scandinavian designs that have both modern and organic forms,
- having functional prominence,
- necessitating interaction with the user, user's active involvement.

The product image set includes armatures, cutlery sets, salt and pepper containers, sieves, lemon squeezers, grinders, and seating units as generic products can be easily recognized and comprehended.

The evaluations of the products regarding biophilic characteristics, dimensions, and values were done through a group of words throughout the study. To put those words out, a set of interviews were held with an expert group of 40 academicians and/or professional designers (1st expert group) 24 female and 16 male members constituted the group, and 31 were academics, while 9 were professionals. Participants had at least one degree of higher education (undergraduate or postgraduate) in Industrial Design with an average of 14 years of experience. The academicians were employed in the departments of Industrial Design as research assistants, instructors, assistant and associate professors, and professors in various universities. The professional designers had working experience of between 7 and 30 years.

The 1st expert group was asked to generate words, adjectives, phrases, expressions, etc. related to the concepts of 'biophilic', 'non-biophilic', and 'biophobic' by brainstorming through free association. Also, the participants evaluated the 95 products as biophilic, non-biophilic, biophobic, or none. At the end of this phase, we obtained a word set, consisting of 2,238 words, adjectives, and phrases in total; associated with the qualifier of biophilic (N=1.124),

non-biophilic (N=533), and biophobic (N=581). In addition, we acquired a product set consisting of 95 product images that were evaluated as biophilic, non-biophilic, biophobic, or none.

The word pool was examined in comparison with the categorizations of biophilic values, elements, and attributes in the literature on biophilic environmental design which are *A Typology of Biophilia Values* (Kellert, 1993), *General Features of Nature* (Heerwagen, 2003), *Biophilic Elements and Attributes* (Kellert, 2008), *Seven Attributes of Nature* (Heerwagen & Gregory, 2008), *14 Patterns of Biophilic Design* (Browning et al., 2014), *Experiences and Attributes of Biophilic Design* (Kellert & Calabrese, 2015), and *Eight Points of the Biophilic Effect (Salingaros, 2015).* Stephen Kellert's two categorizations became prominent by being the most relevant ones to product design principles and values. Biophilic design elements are suggested in a very detailed way in *Elements and Attributes of Biophilic Design* (Kellert, 2008) while the chart *A Typology of Biophilia Values* (Kellert, 1993) presents more concise and abstract values. All the words in our word pool were distributed into the titles of both charts according to the explanations of each.

The chart (Table 2) "Elements and Attributes of Biophilic Design" (Kellert, 2008) is too broad at some points; yet lacks product-specific design elements and attributes. Since Kellert's (2008) categorization had been proposed for architectural and urban design, no words were listed under the titles exclusive to these realms. For example, the titles about space and light, like 'Geomorphy' and 'Filtered Diffused Light' were not applicable for product design due to the difference of the realm such as scale, design elements, and the environment. Also, the product-specific words in the pool didn't fit under any title of the chart. A bulk of words which needed categories like 'Human Scale', 'Human-Friendly', 'Natural' (as a specific title), 'Aliveness' (as a specific title), and 'Energy' as peculiar to the realm of product design stayed out. Titles like 'Central Focal Point', 'Light as Shape and Form' and 'Complementary Contrasts' remained empty even though they were

Table 3. *A typology of biophilia values (Kellert, 1993, p. 59).*

A Typology of Biophilia Values		
	Definition	**Function**
Utilitarian	Practical and material exploitation of nature	Physical sustenance/ security
Naturalistic	Satisfaction from direct experience/ contact with nature	Curiosity, outdoor skills, mental/ physical development
Ecologistic-Scientific	Systematic study of structure, function, and relationship in nature	Knowledge, understanding, observational skills
Aesthetic	Physical appeal and beauty of nature	Inspiration, harmony, peace, security
Symbolic	Use of nature for metaphorical expression, language, expressive thought	Communication, mental development
Humanistic	Strong affection, emotional attachment, "love" for nature	Group bonding, sharing, cooperation, companionship
Moralistic	Strong affinity, spiritual reverence, ethical concern for nature	Order and meaning in life, kinship and affiliational ties
Dominionistic	Mastery, physical control, dominance of nature	Mechanical skills, physical prowess, ability to subdue
Negativistic	Fear, aversion, alienation from nature	Security, protection, safety

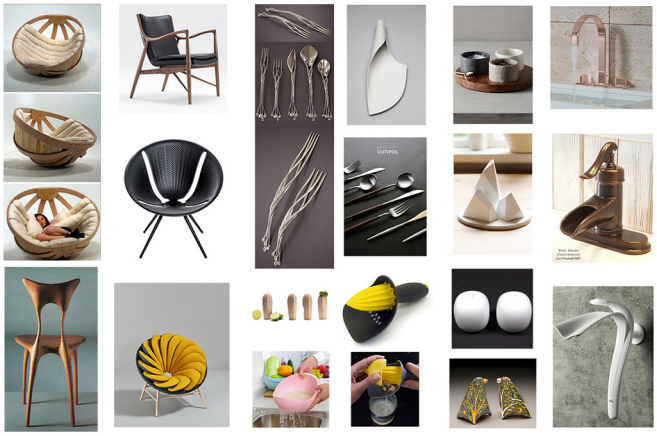

Figure 2. *Product set (N=18) obtained at the end of the 1st expert group study which was used throughout the research (see Appendix).*

expected to be associated with product design. Kellert's (2008) chart 'Elements and Attributes of Biophilic Design' was a functional starting point to reveal the differences between architectural and product design in respect of the biophilic design approach. However, we decided to continue with A *Typology of Biophilia Values* (Kellert, 1993) due to its more comprehensive and abstract formation (Table 3).

The words that were associated with 'non-biophilic' and 'biophobic' were mostly the same even though there were some exceptions. Most of the participants of the 1st expert group found the concept of non-biophilic 'vague'. It appears to be a consistent result considering the infrequency of the concept of 'non-biophilic' and the lack of a detailed definition of it in literature. Similarly, Salingaros (2015) criticized modern architecture and designated it as biopho-

Table 4. *The biophilic and non-biophilic/biophobic words related to the biophilic product dimensions.*

	Biophilic	Non-biophilic/Biophobic
Form	aesthetic, asymmetry, natural, comfort, curvilinear, ecological, ergonomic, flowing, harmonious, natural, plant, plain, tree, useful	cornered, disproportional, geometric, homogeneous, sharp, smooth, straight
Functional	comfort, easy to use, ergonomic, fit for purpose, functional, practical, harmonious, useful	mechanical
Material	animal, archaic, durable, ecological, fit for purpose, flexible, fluid, handmade, healthy, innate, matte, natural, plant, sense of belonging, soft, tree, vivid, warm, wish to touch, wooden texture	artificial, fake, fragile, homogeneous, shiny, sterile
Psychological	adorable, calm, contented, comfort, ergonomic, familiarity, hugging, loyalty, peaceful, positive, safe, sense of belonging, sincere, soft, spaciousness, strong, sturdy, useful, warm, wish to touch	attacker, cold, dangerous, disgust, far-fetched, loneliness scary, unlikeable
Sensorial	bright, calm, matte, spaciousness, soft, tree, vigorous, vivid, warm, wish to touch, wooden texture	cold, darkness, loneliness, sharp, shiny
Semantic	archaic, contented, familiarity, holistic, humanist, interesting, loyalty, positive, still, sympathetic	disgust, geometric, loneliness, unnecessary

bic instead of non-biophilic, due to the characteristics of sharp, perpendicular, and geometrical lines, and lack of details, smooth and shiny surfaces. Thus, the number of qualifiers decreased to two as 'biophilic' and 'non-biophilic/biophobic' since it supports the research question better. At the end of this study, we had a product set consisting of 18 product images (Figure 2) that the 1st expert group mostly agreed on assessing as biophilic or non-biophilic/biophobic; and the word set.

At that point, we did an exploratory study to understand the potential of the word set and the product images. A user survey was designed with the 30 most frequent words in the set and the 18 products to be associated by the participants. The words are in alphabetical order: *aesthetic, alive, aversive, balanced, cold, comfortable, complicated, dangerous, dirty, disproportionate, fear, forced, functional, harmful, harmonious, healthy, hygienic, interesting, natural, plastic, primitive, random, regular, safe, shiny, simple, strong, sympathetic, unknown, warm.* Each word corresponds to three types of identifiers: the first is being biophilic or not, which is defined by the 1st expert group; the second is biophilic values that are stated by Kellert (1993); and the third is the hypothetical biophilic product dimensions, proposed by the researchers as 7 dimensions (*see Table 1*). This exploratory study was expected to provide insight into the participants' experience of taking the survey. A group of 29 participants (2nd user group), took part in this study. 20 of the participants were female and 9 were male, the average age (M=33), and the professions included academics, engineer, attorney, designer, finance expert, news speaker, physician, teacher, and student. 18 of the participants responded to the survey online while 11 of them were observed by the researcher in person during the survey. The participants were given a form consisting of 18 pages with one product image on each and the random-ordered 30 words under the product images. The participants were asked to choose 10 words out of 30 that they associated with the products and evaluate those 10 words on 5 points Likert scale. The participants were also asked if they would prefer to use that product or not. In addition, the participants evaluated their survey experience about clarity, difficulty, and completion period.

The study revealed that the survey took 30 minutes on average to be completed and it was quite a cognitive load for the participants to relate 10 out of 30 words to 18 different products each. On the other hand, 30 words did not constitute that large a set to be distributed into Kellert's (1993) 9 titles and 7 biophilic dimensions of biophilic product definition.

Separating the work of the word-products association and the user preference survey would provide more effective results by allowing us to design a briefer survey enabling a larger reach of participants. Also, assigning experienced designers to associate the words and products would provide more reliable results due to their experience and knowledge of the semantics of products. Since the association work would be done by an expert group, an opportunity to expand the word set had emerged increasing the reliability of the study.

Table 5. *Revised biophilic product definition with its dimensions and qualities.*

Form	Function	Material	Psychological	Sensory	Semantic
Asymmetry	Consistency	Color	Comfort	Color	Connotation
Amorphous	Ergonomics	Indigenious	Emotions	Feeling	Emotions
Balance	Expediency	Natural	Familiarity	Odor	Historical
Ergonomics	Productivity	Texture	Feelings	Rhythm	Identifiability
Geometry			Loyalty	Sound	Story
Identifiability			Safety	Taste	Symbolic Value
Integrity				Texture	
Organic				Vibration	

The word pool was revisited and the repeated words were picked. The near-synonymous words were grouped and eliminated to be represented by the most frequent ones. Thus, the number of words was downsized to 112. The larger the word set, the more detailed and objective work is necessary to distribute the words into Kellert's (1993) biophilic values and the hypothetical biophilic dimensions. And so, another expert group (2nd expert group) comprising 15 academics from the fields of Industrial Design, Interior Design, and Psychology was consulted to match the words to the values and the dimensions. The 2nd expert group was given a form which includes Kellert's (1993) 9 values (Utilitarian, Naturalistic, Ecologistic-Scientific, Aesthetic, Symbolic, Humanistic, Moralistic, Dominionistic, Negativistic) and 7 biophilic product dimensions (Attitude, Form, Functional, Material, Sensorial, Semantic, Psychological) as 'titles' and the 112 words to be matched.

All the titles and matched words were put into a table. The words that 7 members of the 2nd expert group agreed to relate to a title were selected to be used in the rest of the research. Even though 8 to 15 provides the majority rule, acquired words would be significantly lower in the case of selecting 8 agreements. To keep the richness of the data, 7 was preferred to be the threshold. This study showed that the words of biophilic product dimensions cover the ones under Kellert's values. And also, functional dimension words cover the words of attitude dimension. Consequently, the biophilic product came to be defined by 6 dimensions: form, functional, material, semantic, sensorial, and psychological. Kellert's (1993) Negativistic value which indicates biophobia wasn't included as a separate dimension but embedded into each dimension through the non-biophilic/biophobic words. The last version of the word set with the negativistic values can be seen in Table 4.

At the end of this stage, the total number of words was 78; some associated with more than one dimension. Accordingly, the biophilic product definition and its dimensions were revisited based on the second expert group review of Table 1. Table 5 shows the revised version of the dimensions and their qualities which are achieved at the end of the 2nd expert group study.

2.2. Stage II: The effects of biophilic dimensions of products on the user preferences

This stage consists of another expert group study (3rd expert group) and a new user group study (3rd user group), and quantitative analysis methods such as reliability tests and linear multiple regression analysis. The 3rd expert group was composed of 6 groups with 20 participants in each. The participants were chosen according to their academic and/or professional design expertise on the specific dimension of the biophilic product as form, functional, material, semantic, sensorial, and psychological. All participants major in Product Design except the psychological dimension group. That group has participants who are academicians in the field of Psychology besides the designers.

The 3rd expert group was asked to evaluate the 18 products (see Figure 2) regarding the relationship with the words that were assigned to each dimension. The study was held via an online survey that had 18 pages attended

Table 6. *Model summary of Linear Multiple Regression Analysis of biophilic dimensions.*

Dimension	*B*	*SE*	*β*	95% CI		*p*
				LL	*UL*	
Constant	.172	.504		-.897	1.241	.737
Biophilic Functional	.966	.158	.837	.631	1.300	.000
R^2	.701					

Table 7. *Model summary of Linear Multiple Regression Analysis of non-biophilic/biophobic dimensions.*

Dimension	*B*	*SE*	*β*	95% CI		*p*
				LL	*UL*	
Model 1						
Constant	.682	.436		-.242	1.606	.137
Non-biophilic / Biophobic Functional	.854	.144	.830	.549	1.158	.000
R^2	.688					
Model 2						
Constant	2.500	.886		.611	4.389	.013
Non-biophilic / Biophobic Functional	.571	.178	.555	.192	.951	.006
Non-biophilic / Biophobic Psychological	-.528	.232	-.394	-1.022	-.035	.038
R^2	.769					

to each product image. The words that belong to each dimension were placed below the image with a 5 point Likert scale. 1 indicated "Not relevant at all", and 5 indicated "Certainly relevant".

The evaluation scores of each dimension were tested for reliability in two sections as biophilic and non-biophilic/biophobic. The reliability tests were run by the software of SPSS 27 and the reliability threshold was set as Cronbach Alpha α>.7) and the Item-Total Correlation coefficient as .25. The words that have negative item-total correlation coefficient values were re-coded by using the complementary value to 5. The words under the reliable threshold were removed from the word set and the average scores of the remainings revealed the scores of the products for every 6 dimensions as both biophilic and non-biophilic/biophobic cases. These scores were used as the predictors, the independent variables of the regression analysis which has been done to analyze how the biophilic dimensions affect the user preferences.

The same 18 product images were used in the user survey which was held online and by snowball sampling without any limitation of age, gender, education level, etc. The participants (N=1.206) were asked to evaluate the products how they preferred to use them via a 5 points Likert scale. 1 indicated "I would certainly not prefer to use it", and 5 indicated "I would certainly prefer to use it".

Therefore, the qualitative data were transferred into the quantitative data as both biophilic product dimensions and the user preferences for a product set (N=18). To understand the effect of the biophilic product dimensions on the user preferences, the data was run on Multiple Linear Regression Analysis by the software of SPSS 27. The analysis was run separately for biophilic and non-biophilic/biophobic dimensions. The biophilic product dimensions were independent variables while the user preferences were dependent variables for both analyses.

3. Results

The results of the multiple linear regression analysis indicate the multicollinearity between the psychological dimension and the semantic dimension in both biophilic and non-biophilic/biophobic cases. The correlation coefficient between the biophilic psychological and the biophilic semantic dimension is .885 (>.8) (p=.000<.05); while in non-biophilic/biophobic case the correlation coefficient is .804 (>.8) (p=.000<.05). Similarly, there is multicollinearity between the biophilic material dimension and the sensorial dimension as the correlation coefficient is .902 (>.8) (p=.000<.05).

The only dimension that has a significant result is the functional dimension ($p_{functional}$= .000<.05) in the biophilic case (Table 6). The biophilic functional dimension explains 70.1% of the variance predicting the user preferences R2= .701, F(1, 16)=37.502, p<.001, 95% CI [.601, 1.300]. Five dimensions other than the functional dimensions has not significant results ($p_{semantic}$= .224 >.05, p_{form}= .768 >.05, $p_{sensorial}$= .722 >.05, $p_{material}$= .525 >.05, $p_{psychological}$= .109 >.05).

Besides, the biophilic psychological dimension has the highest partial correlation value (.402) over the other four ($p_{psychological}$= .109 >.05). The multiple regression analysis was run again

with the removal of semantic dimension to resolve the multicollinearity between the semantic and psychological dimensions and catch the significance value; however, the significance value couldn't catch the threshold (p=.05).

In the non-biophilic/biophobic case, the functional ($p_{functional}$= .000<.05) and psychological ($p_{functionalpsychological}$= .038<.05) dimensions have significant results (Table 7). The non-biophilic/biophobic functional dimension explains 68.8% of the variance predicting the user preferences R^2= .688, F(1, 16)= 35.313, p<.001, 95% CI [.549, 1.158]; while non-biophilic/biophobic functional and psychological dimensions explain 76.9% of the variance R^2= .769, F(1, 15)= 5.205, p<.05, 95% CI [.192, .951] and [-1.022, -.035]. The partial correlation coefficient of the non-biophilic/biophobic psychological dimension has a negative value -.508 ($p_{psychological\_non}$= .038<.05) which means that non-biophilic/biophobic psychological dimension is inversely related to the user preferences.

4. Discussion

The detachment of humans from nature has been getting more compelling with the developments in technology and urbanization, which in turn is associated with many psychosocial problems affecting general physical and psychological well-being (Dean et al., 2018). Given that many of the resulting technological and human-made environments are structurally and functionally irreversible, arguably the best approach to restore human well-being may be the nature-centered approaches such as biophilic design (Kellert, 2005). However, to the best of our knowledge, there is no empirical effort in product design literature testing the effects of biophilia on the user preferences of products. In addition, while the biophilic approach has been widely accepted and integrated in Architecture and Urban Design, traces of the same interest cannot be found in the field of Product Design. This shortcoming may be partly due to the lack of a basic study in the field of product design to identify the qualities that make a product biophilic.

In this regard, the primary aim of the present study was to investigate the defining characteristics of the concept of biophilia in product design. After all, as the important parts of the built environment, products are worth investigating in terms of the biophilic approach. The second aim of this study was to evaluate the effects of biophilic design features on user preferences. Thus, determining biophilic product dimensions and characteristics along with investigating their effects on the user preferences would be an important contribution to the product design literature for its future development and integration.

The study consisted of two stages. The first stage focused on identifying the product-specific biophilic dimensions and determining the defining characteristics of a biophilic product, the second stage focused on investigating the user's preferences of biophilic dimensions of a product. Here, several significant aspects of the present study will be highlighted.

First of all, a series of empirical studies providing us with both qualitative and quantitative analysis which aimed at the literature gap in biophilic product design was held. A whopping total of 1.414 participants served as users (N = 1.239) and experts (N = 175) in the study, one of its kind for its sample size.

As the closest fields to industrial design, architecture and urban design had already provided biophilia literature with a body of categorizations on biophilic elements, attributes, and values. Taking advantage of this, we included those categorizations in our framework for further inspection within the context of biophilic product qualities. Our first findings revealed that they were too comprehensive for products at some points while lacking some of the product-specific elements. Therefore, at the end of the first stage of this research, we obtained a set of biophilic dimensions of products on the grounds of, but not limited to, biophilic architectural and urban design principles. "*A Typology of Biophilic Values*" (Kellert, 1993) as the most relevant categorization to products by being more conceptual and inclusive was chosen as an initial point and his set of values

were employed throughout the empirical studies carried out to identify the biophilic product dimensions.

Another significant contribution of this study is the higher resolution it provides to the definition of a biophilic product. We hypothesized at the outset that qualifying a product as biophilic should be based on a multidimensional evaluation rather than a binary one such as biophilic or not. Consistent with our prediction, our results indicated that the definition of biophilia in products accommodated multidimensionality. Thus, a product might be defined through 6 biophilic dimensions as form, function, material, semantic, sensory, and psychological dimensions.

The results of the second-stage works investigating the role of the biophilic dimensions in the end-user preferences revealed that the functional dimension was significantly effective on the preferences in both biophilic and non-biophilic cases. On the other hand, the psychological dimension was effective on 'not to prefer' in the non-biophilic cases. Moreover, the significant multicollinear relationships between the psychological and semantic dimensions and between the material and sensorial dimensions could be associated with a need for a reduction in the number of dimensions which conveniently simplifies the definition of biophilic product.

Another interesting finding of this study was that although we have evidenced at the first stage of the study that form, material, semantic and sensory dimensions were cognitive criteria available in the evaluation of products regarding biophilia, none did reach the level of statistical significance in predicting the preferences of end-users. This finding may point to several important aspects of user preferences. First, end-users typically prefer using simpler mechanisms, as opposed to more complex ones in their decision-making. This is particularly true when the task involves evaluating through 2-dimensional (2D) images since some of the cues signaling all the qualities of the product have become rather vague in a 2D version. The cognitive complexity of the assessment of a product presented in a 2D plane may be too high for a layperson to process, even though it is quite low for an expert. Hence, the end-users would be expected to employ a cognitively more parsimonious strategy of preference which is presumably based on criteria that are more critical to them. In line with this expectation, the user participants in our study used only the functional and the psychological criteria in their evaluations. Thus, we hypothesize for future inquiries that these two criteria may be the most applicable of all others to real-life situations, especially, when there is only a limited amount of information available about the product of interest.

Second, the task required for the user participants to perform was assessing the products which had neither personal or sentimental nor possessional relations with themselves. Since the products present experiences to users mostly in emotional, social, and cultural contexts (Heskett, 2002; Margolin, 1997) the end-users would be likely to make evaluations based on a wider range of criteria for the products with which they are in emotional/possessional relationships. But as Boztepe (2007) indicated products create value in the eye of the user as they interact with their user and fit their daily lives. Since the products evaluated were not in the reach of users, those four dimensions might have not manifested themselves due to the 2D exposure procedure we followed in this study. Apparently, future studies are needed to test the effects of emotional, possessional, and functional variables of user-product relations.

The initial structure of this research was constructed on biophilic design aspects in Architecture and Urban Design. Together with empirical data collected specific to the research design and experience gained along the way, led to determining product-specific biophilic dimensions attributed to the realm of Industrial Design. Architecture and products differ explicitly from each other regarding scale, lifecycles, materials, spatiality, mobility and locality, uniqueness, and more can be listed. The reflections of these differences in terms of biophilic aspects and dimensions in our study would be

more informative when the end-products are examined with users' relations to them. For instance, a building is often less individual and personal compared to an industrial product which even may include intimacy.

This intimate relationship is often described as an emotional attachment (Desmet & Hekkert, 2007; Norman, 2004) of the user to the product. Norman (2004) also draws attention to product customization as it reinforces the bond between the user and the product. Products offer different values. Owning a product signifies something beyond its utilitarian value; for example, symbolic values imply social status and prestige (Baudrillard, 1981). Although in architecture and urban design this personal attachment has a weaker character, adoption of habitat aspects such as light, water, color, and vegetation are theorized as being inherent in everyone. These characteristics have been suggested as evolved psychological mechanisms by several theories such as Prospect & Refuge Theory by Appleton (1975), Savannah Hypothesis by Orians (1980), Habitat Selection Theory by Orians and Heerwagen (1992), Attention Restoration Theory by (Kaplan & Kaplan, 1989). However, the ways we interact with spaces and tools are different in evolutionary terms, even though they are both human-made structures (Boyer & Barrett, 2016). Thus, these theories do not shed light on the adaptive roles of design products.

A product is, in a sense, an extension of the user. After all, the desire for possessing a tool to "get the job done" has been one of the most significant cognitive adaptations humans acquired through their long evolutionary history (Petroski, 1992). Each tool is a design product, and we have been using them for getting and preparing food, carrying and storing, making clothing, recording information, art and music, and for many other things since the stone age. Making tools advanced humans to overcome survival needs like hunting, and foraging (Barrett, 2016), also making other tools (Petroski, 1992), and became one of the most significant indicators of cultural evolution (Whiten et al., 2011). Given its universal role in survival and reproduction, this powerful urge to make, own, and use tools still heavily influences our product preferences in our minds today. As Boradkar (2010) indicated these things serve to enhance, not only the physical and mental competencies but the personal and communal sense of identity of people. Our end-user data clearly support this compelling presumption. Evidently, our user participants distinctively relied on psychological and functional aspects of the products in their decision of preference, which presumably reflected the long-lived desire of being in the personal distance with the product, and using it to achieve goals.

The question of why user-participants made their evaluations based on the function begs further elaboration, probably by referring to the cognitive mechanism of product evaluation. Biophilic preferences of products of the user participants were dominated by the product functionality. This observation calls forth an interesting aspect of biophilia as a cognitive capacity. Our preferences of products are determined both by the information provided by a product and the associated information available in our long-term representations. Accordingly, the congruency between a product and the best-fitting mental representation of the product creates a sense of familiarity in the user's mind. When there is a lack of familiarity, the product initially tends to elicit aversive reactions from the user. This is produced by a fast and dirty emotional system. As the familiarity increases, a slow but clean system of evaluation kicks in. Finally, whether appetitive (positive) or aversive (negative), our impressions of the product are stored in the long-term representational system (namely the long-term memory).

This representation system of biophilia (including both biophilic and biophobic representations) plays a role in our product preferences because the neurobiological markers which guide the emotional process in choice behavior have been fashioned by evolutionary mechanisms (Bechara & Damasio, 2005). For the same reason, natural environments are consistently preferred

to human-made environments (Kaplan, 1992), viewing pictures of nature scenes decreases physiological distress (Ulrich, 1983, 1986), and the presence of flowers in a hospital room increases the recovery rate of patients (Ulrich, 1986).

Toolmaking for protection from predators, hunting, gathering, and making other tools has been essential for human survival not only during the Pleistocene era but also now in the modern era (Bailey & Geary, 2009). This study reveals that user preferences of products are significantly under the effect of functional dimension. We may say that there is a strong similarity between the toolmaking for survival in savanna and the architectural needs of sheltering, hiding from predators, watching the prey, finding food, etc. regarding their importance being still valid today (Biro et al., 2013). Also, attraction to artifacts and object-guided learning have an adaptive role in human evolution (Fragazsy et al., 2013). Then, the user makes their preference regarding the potential fitness contribution of the product. This stage calls forth the functionality of the product.

The aversive attitudes of the users towards the non-biophilic/biophobic psychological dimension, which we observed in the present study, are compatible with the biophobic responses of organisms to biophobic objects in their natural environment. Biophobia is an inherent mechanism that helps the living being to survive with the help of fear, revulsion, and avoidance (Bracha, 2004). Consistently, non-biophilic/biophobic functional and psychological dimensions of products are significantly effective on the user preferences. We may conclude that biophobia still has a strong effect on modern human preferences. In every stage of the study, the strength of biophobia made itself evident. The interviews with the 1st expert group concluded with more consistent words of biophobia than the words of biophilia. Also, the analysis of the effects of biophilic dimensions on the user preferences showed that the non-biophilic/biophobic psychological dimension had significant results while the biophilic psychological dimension couldn't reach the significance threshold.

The number of the product images did not exceed 18 not to pose cognitive load for the participants in the empirical studies. Since the common ground of all studies is the set of the product images, the sample of the regression analysis needed to be N=18. This small sample has occurred as the limitation of the study which can be overcome by increasing the number of the products to achieve more efficient and comprehensive results in further studies. Thus, the significance value of the form, material, semantic, and sensorial dimensions may increase. For instance, the biophilic psychological dimension couldn't reach the significance threshold, however, it has the second-highest partial correlation coefficient after the biophilic functional dimension. Higher significance values would be expected in a larger sample. Besides, a physical evaluation, interacting with the products in person, rather than over a digital representation would enhance the quality of the users' evaluation as a further study suggestion.

Alternatively, a further study could be formed through the products which the users have already possessed. The researchers would be sure that those products have been preferred and possessed, thus having a connection with their users. In addition to enlarging the product sample size, the user participants would be diversified to get an insight into how the cultural and geographical differences manifest into biophilic dimensions.

Relating the concept of possession -an issue in material culture studies- with biophilia in users' tendency can be a promising frame for further study. In understanding the subjective nature of possession apart from objective limitations such as purchasing power, level of education, aesthetic literacy, biophilic properties may be an operational tool in revealing the dimensions behind ownership of objects, their meanings, and evocation embedded in materiality. The functions of products surpass utility functions and they respond to human's search for meaning, constitute one's and society's material memories, provide communication and interaction

(Boradkar, 2010; Kwint, 1999; Norman, 2004). All these issues beyond utility are anywise related to culture. Biophilic approaches, in general, adopt the idea of interaction between nature and nurture; accepting natural and cultural approaches as complementary rather than conceptualizing them as dichotomous since they are the products of the evolution of the human mind and they are in a sustained biotic relationship (Chudek et al., 2016; Kellert, 2005; Wilson, 1998, 2008). Hence, the dichotomy between nature and culture has been effectively criticized by theoreticians such as Harraway (1991) and Latour (1999/2004). Extending material culture studies through the lens of biophilia within the dissolution of such dichotomy would be a significant contribution to the field.

Within the introduction of new modes of products such as services, intangible goods, and digital possessions in virtual environments, experiences, and interaction where design plays a crucial role, biophilic dimensions are worth searching especially in terms of psychological, functional, and symbolic means. The expansion of the boundaries of product and production realms might be a significant actor within the current research environment based on the co-evolution of technology and nature. The studies on employing technology to enforce biophilia and nature-relatedness (Buettel & Brook, 2016; Kahn, Jr., 2011) seem to be a promising field for design to be involved. Uncovering the potentials of biophilic design and introducing metrics related to biophilic dimensions of design to reach higher human centeredness leading to business success can be promising in calming down tensions between different actors in the design and production realms.

To conclude, this study doesn't claim to produce absolute judgment on the biophilic product qualities. Instead, it is one of the steps paving the way to "biophilic product design principles". Both the biophilic product definition and the word set may be improved by considering the multi-faceted structure of the products and may enrich the literature related to biophilic product qualities.

Acknowledgements

This research was funded by ITU Scientific Research Projects Coordination Unit (BAP).

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Appendix

[Cradle]. (n.d.). Pinterest, shorturl.at/krtA1

[Cube-formed salt and pepper container]. (n.d.). Pinterest, shorturl.at/irxJN

[Cutipol Cutlery]. (n.d.). Pinterest, shorturl.at/jEW15

[Farmhouse kitchen faucet]. (n.d.). Pinterest, shorturl.at/cnyX2

[Finn Juhl Lobby Chair]. (n.d.). Pinterest, shorturl.at/iqHLU

[Geometric salt and pepper container]. (n.d.). Pinterest, shorturl.at/horzA

[JOSEPH JOSEPH Catcher Citrus Reamer]. (n.d.). Pinterest, shorturl.at/ilosE

[Juice Bruce Lemon Squeezer]. (n.d.). Pinterest, shorturl.at/bAFKS

[Leafy Faucet]. (n.d.). Pinterest, shorturl.at/vDTV1

[One Piece Knife]. (n.d.). Pinterest, shorturl.at/rCHT1

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