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Exploring Visual Biophilic Interior Design Features in Homes: An Experimental Study through a Virtual Environment Design

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Abstract: This study aims to identify the most important implicit visual elements/features of the biophilic design (BD) perceived in interior environments using virtual reality (VR) technology. It also suggests ideas for expanding the concept of BD in residential environments and emphasizing its psychological function. The study employed participation observations (a representative sample of ten heads of the family from Medina) when VR was applied to redesign their living rooms; semi-structured one-on-one interviews were conducted after the experience. The concept of BD in residential environments was developed using an inductive approach. The results showed that all participants perceived more than 50 percent of the visual BD features included in the design. Environmental features of color, water, and natural materials were most easily perceived; among natural shapes and forms, biomimicry, botanical motifs, shapes resisting straight lines, and biomorphy were perceived more compared to egg-shaped, oval, and tubular forms. Although arches, vaults, and domes, as well as biomimicry, were mentioned in the interviews, they were not mentioned in the spontaneous description based on observations. This study introduces a research method for applying VR to the perception of BD. The study selected ten families and redesigned their living rooms with BD elements. The participants viewed the modified environment through VR glasses and expressed their feelings during the interviews. Data analysis was conducted to determine the significance of each BD element and the degree to which it was perceived. Exploration with advanced VR technology that allows participants to walk among the redesigned interiors is required.

Keywords: *Interior Design, Biophilic Design, Visuals, User Perception, Virtual Reality Technology, Quality of Life*

Introduction

The term "biophilia" became popular when biologist Edward Osborne Wilson explained, in his book *Biophilia*, humankind's deep attachment to nature and how that was rooted in biology (Wilson 1993). The "need for nature" has been explored as a genetic human behavioral trait (Browning, Ryan, and Clancy 2014; Downton et al. 2017; Ibrahim 2019; Ryan et al. 2014). Furthermore, various semantics developed within the fields of biology and psychology have been adapted to the fields of neuroscience, endocrinology, architecture, and so on, with a desire to (re)connect nature and natural systems (Browning, Ryan, and Clancy 2014; Downton et al. 2017).

Biophilia is the innate human need to belong to nature; thus, we must take advantage of the natural environment that positively affects physical, spiritual, social, and psychological well-being (Downton et al. 2017) to improve the quality of life of individuals and societies.

While biophilia is a theoretical concept, biophilic design (BD; Ibrahim 2019; Kellert 2008; Ryan et al. 2014) is, at the international level, a process that advances a sustainable design strategy that includes reconnecting people to the natural environment. As Kellert and Calabrese (2015) explain, BD seeks to create a good habitat for people as biological organisms in a built environment that enhances their well-being in the modern era.

In this context, BD can reduce stress; improve cognitive functions and creativity; support the human body's emotions, moods, and strength; improve well-being; and hasten the healing process. As the world's population continues to urbanize, these traits have become increasingly important (Browning, Ryan, and Clancy 2014). Human beings instinctively seek colors, designs, patterns, sounds, and smells found in nature, and some of these influences, which are the core tenets of BD, support mental, emotional, physical, and spiritual health (Ibrahim 2019; Kellert 2005).

According to Kellert (2008), two constraints hinder effective BD: our limited understanding of human biology and its tendency to place value on nature and our limited ability to transform this understanding into specific approaches to the design of the built environment. Over the last decade, studies related to BD have explored its effects on various aspects of daily human life, including both the outer and inner spaces of cities, buildings, building façades, urbanism, landscapes, and interiors. Studies on biophilic interior design (BID) consider both real and virtual environments (VE).

Browning et al. (2020) determined that exposure to nature via mobile virtual reality (VR) phones for six minutes generated an impact equivalent to six minutes of outside nature exposure, while sitting inside with no exposure to nature had less impact than the other two conditions. Virtual and outside nature exposure resulted in a slight improvement in physiological excitement related to positive impact, whereas only the outside nature condition demonstrated a considerable positive impact.

Mollazadeh and Zhu (2021) conducted a literature review on the applications, limitations, and capabilities of VE for BD. They found that the VE could support critical features of BD studies, representing combinations of biophilic patterns, providing multimodal sensory inputs, simulating stress induction tasks, supporting the required exposure time to observe biophilic patterns, and measuring the biological responses of humans to the natural environment (Mollazadeh and Zhu 2021). Nevertheless, the literature review revealed many aspects of user experience to be considered in a virtual biophilic environment, such as "VE experience dimensions, user-related factors, cybersickness, navigational issues, and possible limitations of VE sensory input" (Mollazadeh and Zhu 2021). They have specified various prospects for further research in this area. In this study, VE was used to explore users' visual perceptions of (BD) attributes.

VE and VR

VE is an environment produced through "computers and experienced by participants" (Loomis, Blascovich, and Beall 1999; Mollazadeh and Zhu 2021). It is considered a "communications medium" (Ellis 1994; Mollazadeh and Zhu 2021) and defined as the transformation of "digital representations" into "a perceptible experience" and is both a "fictional" and "existing actual environment." Mollazadeh and Zhu (2021) revealed that the most developed aspect of VE is VR, which represents a particular experience for (wealthy) users.

VR is "an artificial environment experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment" (Merriam-Webster, n.d.). Nukarinen et al. (2022) note that the most important advantage of VR is the opportunity to enjoy an experience based on different perceptions. Dimensions that measure the connective aspects of restoration are needed to explore how immersive reframing affects user perceptions and behaviors.

Recent innovations in technology provide rich sets of tools to explore the effects and benefits of BD elements on users' well-being, perceptions, preferences, behavior, and reactions. Based on user responses to certain design elements (window size) within a built environment, Cha et al. (2019) conducted a study on user environment satisfaction using a new VR modeling method in VE and real environments with a representation that is similar to the physical environment of windowed spaces. The results showed that VE is an appropriate representation of the physical environment in terms of the characteristics of windows. In addition, user satisfaction with the physical and virtual spaces was the same, with users conveying higher satisfaction with their senses of visual comfort, interior space, and openness. This was a considerable step toward exploring the various design elements of windowed office spaces. Investigations and studies have shown diverse reactions of occupants (e.g., psychological, cognitive, physiological, and emotional) to different window sizes, forms, and positions in a VE.

A VE can represent open-air and interior biophilic built environments. However, experimental studies on BD in built environments that examine human responses to natural elements are limited (Mollazadeh and Zhu 2021). In VE, most information appears as visual stimuli. VE developers have focused on primary sensory cues (Cha et al. 2019; LaValle 2017). The level of immersion is increased through a combination of coherent sensory inputs that generate the participant's sense of presence in the VE (Mandal 2013; Mollazadeh and Zhu 2021).

Accumulating sensory stimuli expand the sense of reality and affect human physiological and behavioral responses. Although most studies have only incorporated visual and auditory stimuli, Mollazadeh and Zhu (2021) believe that VE can be perceived and experienced through various representations and forms. Muhanna (2015) specifies that the level of immersion experienced by a participant determines the integrity of the VR system in providing a VR experience. Muhanna (2015) classified VR systems into (a) non-immersive

systems, the basic type in which users can cooperate with VE beyond computer screens but are not immersed, (b) partially immersive systems, which expand user immersion, and (c) fully immersive systems. Mandal (2013) clarifies that fully immersive systems ensure stereoscopic three-dimensional (3D) effects in a scene. Mollazadeh and Zhu (2021) considered the use of Cave Automatic Virtual Environments (CAVEs), a subcategory of fully immersive systems, in room-based VR technology. However, this study examined VE through 3D simulated environments. Spatial designers can easily test hypothetical designs and work using VE for visualization, design review, and decision-making (Portman, Natapov, and Fisher-Gewirtzman 2015).

By creating different tests and tasks, spatial designers can help gather real-time data. When people are immersed in a virtual natural environment, physiological, psychological, and/or cognitive responses to virtual stimuli can be collected by researchers (Mollazadeh and Zhu 2021). Many features (e.g., age, gender, childhood experience, and familiarity) developed through technology can influence the impact of virtual biophilic environments on individuals.

From Interior BD to Biophilic Virtual Interior Space

Interior BD Attributes

Kellert (2008) proposed a list of seventy-two features as attributes of BD organized into six categories (Figure 1). Building on fifty-four of the seventy-two features proposed by McGee and Marshall-Baker (2015), Kellert generated the Biophilic Design Matrix (BDM) to perform BD for interior spaces because some of the seventy-two features were found to be more suited for landscape and architectural applications than for interiors (see Appendix A; McGee et al. 2019).

Figure 1: Elements and Corresponding Attributes of BD
Source: McGee et al. 2019

Xue et al. (2019) identified three main aspects of BD: biophilic infrastructure, sensory design, biophilic setting, and performance. Based on these aspects, twenty-five strategies were listed for employing BD. Putri and Pawestri (2020) divided these twenty-five strategies into five physical elements that form space, that is, visual, auditory, olfactory, thermal, and tactile elements. The visual element contributes the most to perceiving space; thus, they focused on visual strategies as the basis for designing virtual learning spaces.

Putri and Pawestri (2020) identified eleven visual (BD) strategies that could be applied and tested in designing virtual interior spaces, including window properties, indoor potting plants, visual characteristics of walls, artworks, ornamental design, surface pattern design from the natural environment, and natural material selection (e.g., wood, bamboo, and rock). They concluded that the existence of different forms (e.g., plants and natural motifs, textures, and materials) of natural visual elements in the interior space created pleasant feelings among participants. They declared that future research could estimate the reliability of measurement results using 3D modeling images and VR to generate an ideal recommendation with real environmental conditions. Focusing on the relationship between these design elements and their effects on atmospheric perception (Dalay 2020), this study aims to

- identify the most important visual elements/features of BD that can be easily perceived in interior environments (living rooms) using VR technology.
- propose ideas to develop the concept of BD within residential environments and activate its psychological functions.

In this context, we address the following study questions:

1. What are the most important elements and features of BD (living rooms) that are visually easy to perceive?
2. What are the most important reference guidelines for employing BD elements and features to enhance an individual's quality of life while providing the least positive impact on the user psyche?

Methodology

This study relied on a qualitative approach (Figure 2) using analytical and experimental methods. The existing literature was analyzed to construct concepts related to the effects of incorporating natural elements into spatial design and their role in improving quality of life, that is, the concept of BD, its elements, features, and applications, the use of VR technology in BD, and so on.

An experiment was conducted to explore the level of user responses by applying BID elements/features to a virtual residential environment (living rooms) and, then, classifying these elements into easy-to-perceive, medium-perceptual, and difficult-to-perceive features. The experimental method involved collecting observations made by participants when they were presented with their own living room redesigned using VR and data from semi-structured one-on-one interviews after the experience. This study was conducted in the Medina region of the Kingdom of Saudi Arabia in 2021.

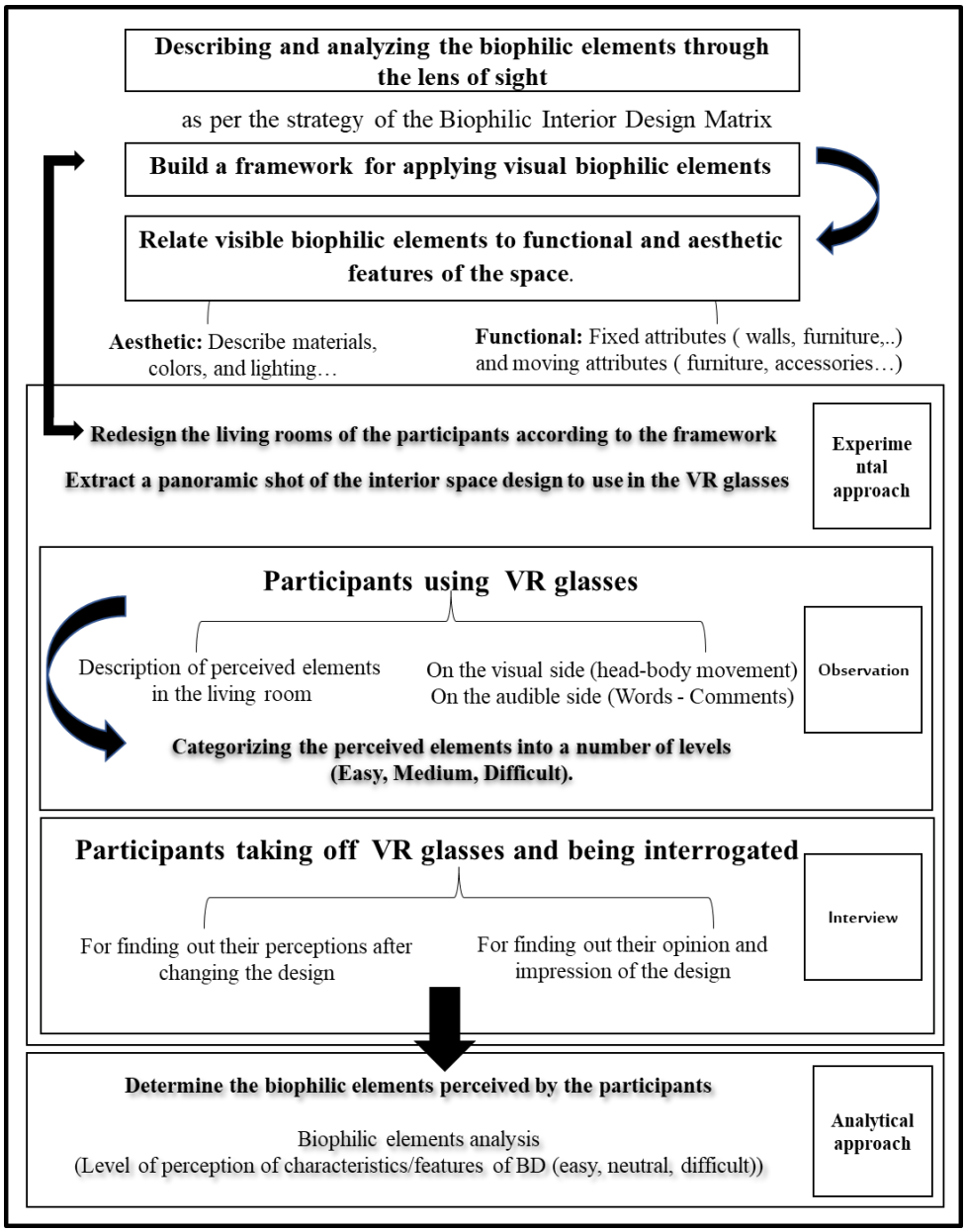


Figure 2: Research Design

Study Sample

In the first stage, the design of the experiment was presented to a group of colleagues in the field of interior design. In the second phase, a pilot experiment was conducted on a family member to check for any possible difficulties. These two stages made it possible to examine the effectiveness of the experiment and the instrument (observation and interview questions).

During these stages, after proposals were presented regarding the level of application of the elements/features of BD in living rooms, it was agreed that in ten cases, elements/features of BD would be installed, and the same method was adopted in all cases to redesign the spatial environment for effective results.

The study sample comprised ten families residing in a region of Medina (Northern, Southern, Eastern, or Western) in the Kingdom of Saudi Arabia. A minimum of two families was identified in each region. The Al-Madinah Al-Munawwarah region was chosen because the researchers lived in the same region, which facilitated the study procedures and application of the experiment. The sample was selected after contacting local district centers that nominated community members who would consent to a scientific research experience; they were subsequently contacted to check whether they agreed to participate in the study.

The sample was limited based on fulfilling the following set of criteria:

- Each family should be of Saudi nationality.
- Each family should comprise two parents and their children, and the number of apartment users should range between four and six people.
- Adult participants should be 24 years and over to ensure accuracy in describing the experience.
- Education level of high school graduate or equivalent.
- Each family must live in an apartment (owned/rented) consisting of four rooms.
- The living room area should range between 20 and 40 m^2.

Data Collection Procedures

The data collection procedures were divided into two stages as follows:

Studies

Step 1: The elements of BD are described and analyzed by linking perceptions with the sense of sight (Dalay 2020) according to the strategy of the BID Matrix (BID-M; McGee and Marshall-Baker 2015), as shown in Figure 3. This link is important for building a framework for applying visual BID elements/features when redesigning the interior environment of living rooms.

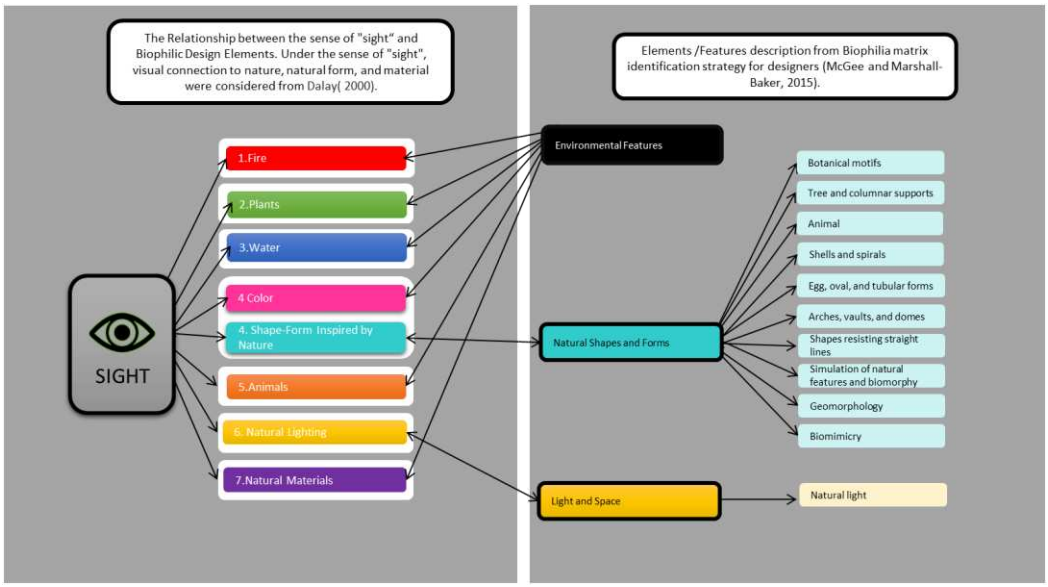


Figure 3: Relationship between Sense of "Sight" and BD Elements/Features

Step 2: The functional and aesthetic characteristics of the existing space were described and analyzed using an Excel sheet. The interiors were analyzed by designing a table with interior space data (i.e., image, area, plan drawing, and main interface drawing). Next, the interior space was described at the functional level by relating it to the properties of fixed elements (walls, openings, etc.) and moving elements (furniture and accessories), their existing distribution, zoning, ergonomic data, and entropion. The space was also defined at the aesthetic level by describing the materials, colors, and lighting used.

Step 3: The application levels of the BID elements/features were studied according to Table 1.

Table 1: The Levels of Application of BD Elements/Features on the Interiors

	Elements of BD	*Features of BD*	*Location in Living Room Space Elements*						
			Walls	*Openings*		*Ceilings*	*Flooring*	*Furniture*	*Accessories*
				Window	*Door*				
Sight	*Environmental Features*	Fire							v
		Plants				v			v
		Water							v
		Color	v	v	v	v	v	v	v
		Animals							v
		Natural materials		v	v		v	v	v
	Natural Shapes and Forms	Botanical motifs	v						v
		Tree and columnar supports						v	
		Animal							v
		Shells and spirals						v	v

		Egg, oval, and tubular forms						v	v
		Arches, vaults, and domes	v	v	v				
		Shapes resisting straight lines				v		v	
		Simulation of natural features and biomorphy							v
		Geomorphology		v					
		Biomimicry							v
	Light and Space	Natural light		v					

Experiment

The experiment was carried out over three weeks as follows:

1. The researchers visited the family to explain the study, obtain their consent to participate, and photograph the living room in order to redesign it.
2. A second visit was conducted to develop the VR experiment, with the homemaker as the main participant, considering her role as the head of the household in the Saudi family.

Following the presentation of the redesigned space, observations and interviews were conducted.

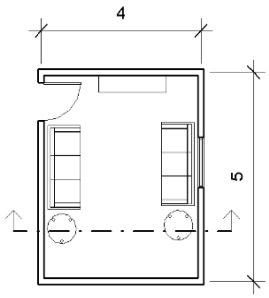
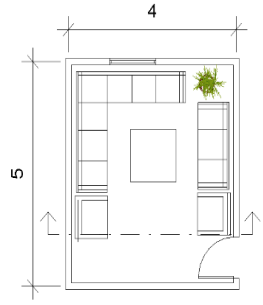
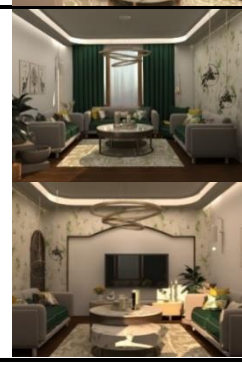
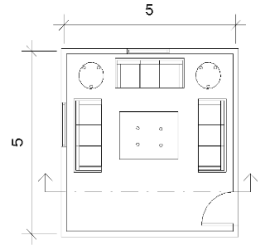
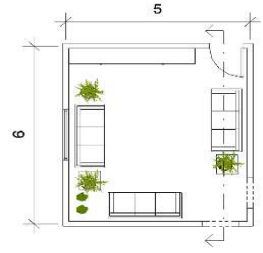
1. Phase 1: Redesigning the interior spaces

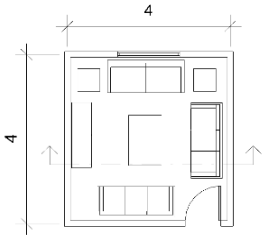
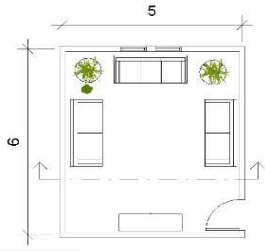
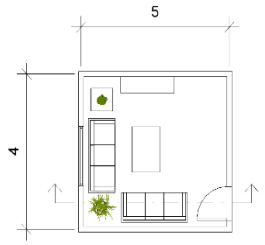
- Step 1: Redesigning the existent space and transposing it on VR

The plan was approved for each living room, and the interiors were redesigned by including the specified visual elements/features of the BD, as shown in Table 1. The concept of VR is based on a set of axes: the first is related to sensory perception and sight, the second to the user's ability, and the third to the necessary equipment (Saffo 2014).

- Step 2: Using VR technology

A space diagram was constructed using RIVIT 2020. The chart was exported to the 3ds MAX 2020 visualization program. The existent space was redesigned according to the levels of application of the various elements/features of the dynamic design in the interior space matrix using 3ds MAX 2020, 3D66, and 3Dsky sites. A 360° panoramic image output was derived. The panoramic image was exported to Momento360 to extract the VR. The space after BD is viewed using VR glasses.

No.	2D Plan Before	3D Picture Before	3D Picture After
1			
2			
3			
4			

5			
6			
7			
8			

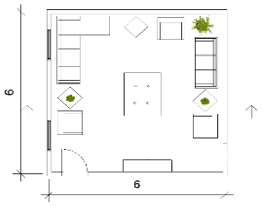
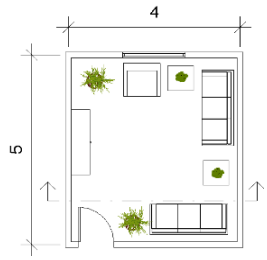
9			
10			

Figure 4: Redesigned Living Rooms

2. Phase 2: With participants (observations and interviews)

This part of the experiment was conducted according to the following steps:

- Step 1 (Consent sheet): Before the participant was asked to wear the VR glasses, a complete idea was presented along with the stages of the experiment, and the participants' roles in the various stages were explained before they signed the consent forms.
- Step 2 (Observations): While the participants wore VR glasses, the researchers focused on the following:
  - The visual and audio aspects of the participants' reactions were recorded by observing their interaction with the design (i.e., the movement of the body in space and the movement of the head), the impression made by the design as expressed through words and comments, and the participants' difficulties, if any.
  - The spatial element description was provided by the participants through an audio recording representing what was seen when wearing glasses. Researchers noted all the described spatial elements and those that were perceived visually (the matrix of the BD element features vs. spatial elements).

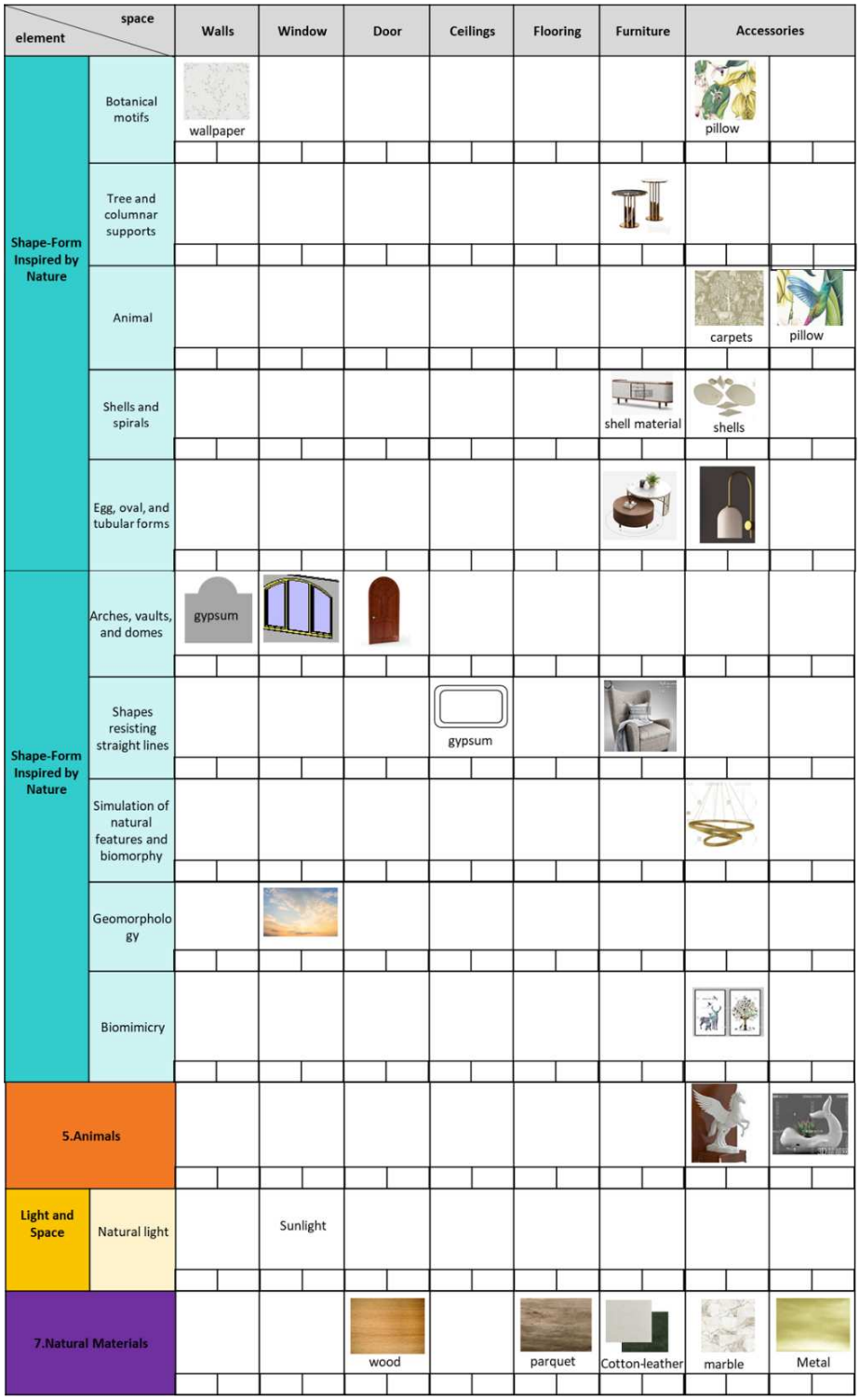


Figure 5: Observations for the Characterization of BD Elements/Features vs. Spatial Elements

The researchers experienced the following problems while carrying out the operations:

- Access to Participant Cases: challenges in obtaining samples and obtaining consent to participate
- Consent to Participate: Obtaining permission to share private living room images was difficult.
- VR is a new method used without proper understanding.
- Gender of Participants: Owing to sociocultural norms and practices, male participants could not be examined, and the experience was limited to women.
- Adverse Consequences of Use: When using VR glasses, people suffer dizziness or headaches.
- Time required for each experience
- Step 3 (Interviews): After the participant removed the VR glasses, questions were asked using an interview card.
    - Instrumentation and development of the interview: A template for the interview card was built to collect the basic data that supported the study.

The interview information was collected with the following aims. First, participants' opinions about BD and the impression and impact of BD applied in their living room were obtained by asking the following questions:

1. Did you like the living room after it was redesigned? Yes/Neutral/No
2. Did the redesign have a positive effect on your psyche? Yes/Neutral/No

Second, the participants' perception of design changes after the inclusion of BD elements/features was assessed by asking the following questions:

3. Can you give me the names of things that remained in your memory/that caught your eye from the space designed in your apartment as accurately as possible?

Third, the most important elements that the participant wanted to achieve in accessories, materials, colors, designs of furniture, floor, ceiling, and walls and their opinion on the inclusion of natural elements in the design of the interior spaces were determined by asking the following question:

4. If you could choose to arrange the elements that you want to achieve in your design of the living room in the future, what order of priority from one to seven would you choose (accessories, materials, colors, designs of furniture, floor, ceiling, and walls)?

Fourth, the opinion of the sample regarding the inclusion of natural elements in the design of the residential environment was obtained by asking the following questions:

5. Do you think it is necessary to include elements of nature in the residential environment design? Yes/No.

The interview questions were presented in Arabic, and data were collected through in-person interviews during the second visit, according to the participants' appointments. Each interview lasted between ten and fifteen minutes. The card includes the following topics:

- The first theme relates to determining the initial information of the sample (families and their dwellings) and includes information about the case and the participant, number of family members, number of rooms, residential area, number of years of residence, the identity of the participant (mother/father/son/daughter), and age.
- The second theme relates to the most important BD elements and features perceived in the design.
- The third theme relates to the priorities of the participants in realizing BD elements/features in the living room.

Data Analysis Procedures

To achieve the study goals of identifying the most important visual elements/features of BD that can be easily perceived in the interior environment (living room) using VR technology and suggesting ideas for developing the concept of BD within residential environments and activating its psychological roles, the data were analyzed in several stages. Table 2 presents the details of the ages of the sample (ranging from 25 to 57 years). Nearly 70 percent of the mothers were aged between 20 and 39 years. Almost 60 percent of the participants had a bachelor's degree. Homeowners comprised 70 percent of the participants, reflecting the emotional link they felt toward their homes. Finally, 60 percent of the living rooms had areas between 20 and 25 m^2.

Table 2: Participant Characteristics

Case No.	*Participants*					*Homes*											
	Age		*Education Level*			*Location in Al Medina Regions*				*Condition*		*Number of Residents*			*Living Room Area (m^2)*		
	20–39	*40–59*	*Middle School*	*Bachelor*	*High School*	*N*	*S*	*E*	*W*	*O*	*R*	*4*	*5*	*6*	*20–25*	*26–30*	*31–36*
1		Y			Y	Y				Y				Y	Y		
2	Y			Y			Y			Y		Y			Y		
3		Y		Y		Y				Y				Y	Y		
4	Y			Y				Y		Y			Y			Y	
5	Y				Y			Y			Y	Y			Y		
6	Y			Y				Y			Y		Y			Y	
7		Y	Y						Y	Y				Y	Y		
8	Y				Y		Y			Y			Y			Y	
9	Y			Y					Y		Y			Y			Y
10	Y			Y		Y				Y		Y			Y		

Note: O = ownership; R = rental.

The participants were briefed on the purpose of the study and assured of the confidentiality of their information and the use of the study only for research purposes. The participants were also informed that they could withdraw from the study at any time. In the

first stage, the matrix for redesigning existing living rooms is defined by transposing interior BD elements/features into spatial design elements. Color coding was used to translate the correspondence of each element to the interior spatial element (see Appendix B).

In the second stage, from the observations, two phases are considered:

1. Phase 1: Notes and comments were collected and transcribed, focusing on
   - the visual aspect of the participant's interaction with the design
   - the participant's impression of the design (e.g., comments at first sight, body movement in the void, head movement)
   - difficulties expressed
2. Phase 2: Participants' perceptions of spatial elements via the virtually redesigned living room were analyzed separately, first in preliminary tables for each case and, then, unified into a single table for all cases.

Data obtained from the VR experiment were aligned according to the following steps:

1. Step 1: Participants' descriptions while wearing the VR glasses were analyzed separately based on the following considerations:
   - Spatial elements that were described were considered as the perceived elements.
   - Each pronounced spatial element mentioned by the participant was coded as (1) when an element was perceived and (0) when it was not.
   - Each perceived spatial element achieved a set of characteristics/features of BD, as per Table 1 (see Appendix B).
   - The total number of biophilic characteristics/features included in the spatial element (attributes sixty-four) was 100 percent.

For each participant, the percentage of perceived characteristics/features of BD from the total spatial elements was determined by dividing the sum of the number of perceived characteristics/features of BD in the perceived spatial elements by the total number of characteristics/features of BD included in the design and multiplying this by one hundred (see Appendix C). The Likert trilateral scale was used to determine the perceived characteristics/features of BD existing in the perceived spatial element; then, the level of perception of the characteristics/features of BD (i.e., easy, neutral, difficult) was determined, as indicated in Table 3.

Table 3: Data Analysis of Perceived Element/Features of BD Existing in the Perceived Spatial Element in Each Case

Perceived Features of the BD Existing in the Perceived Spatial Element in Each Case	*Between Zero and Thirty-One*	*Equal to Thirty-Two*	*Between Thirty-Three and Sixty-Four*
Percentage of perceived features of BD existing in the perceived spatial element in each case	0%–49%	50%	51%–100%
Perception of features of BD	Low	Neutral	High
The level of importance of perception of the elements/features	Not important enough to perceive	Neutral to perceive	Important to perceive

2. Step 2: Data were placed in a table that included the details of all participants/cases. Data were analyzed according to the number of participants who perceived features of the BD existing in the perceived spatial element in all cases (see Appendix C).

The percentage of participants who perceived features of BD in the perceived spatial elements in all cases was estimated by dividing the number of participants who perceived features of BD in the perceived spatial elements by the total number of participants (ten) and multiplying this by one hundred.

The value of the perception level of BD features was determined from the Likert trilateral scale, and the importance level of the perception of the elements/features (i.e., important, neutral, or not important) was determined, as shown in Table 4.

Table 4: Data Analysis of Participants Who Perceived Features of BD Existing in the Perceived Spatial Element in All Cases

Number of Participants Who Perceived Features of BD Existing in the Perceived Spatial Element in All Cases	*Between Zero and Four Participants*	*Equal to Five Participants*	*Between Six and Ten Participants*
Percentage of participants who perceived features of BD existing in the perceived spatial elements in all cases	0%–49%	50%	51%–100%
Perception of features of BD	Low	Neutral	High
The level of importance of the perception of elements/features of BD	Not important to perceive	Neutral to perceive	Important to perceive

3. Step 3: The ease of perception of the BD elements/features was determined, as shown in Table 5.

Table 5: Data Analysis of the Perception Level of BD Elements/Features

Number of participants who perceived features of BD existing in the perceived spatial element in all cases	Between 0–4: Equivalent to 0%–49% of participants and representing the low-value perception of BD features	Equal to 5: Equivalent to 50% of participants and representing the neutral-level perception of BD features	Between 6–10: Equivalent to 51%–100% and representing the high-value perception of BD features
The level of importance of the perception of elements/ features/number of participants who perceived	Not important to perceive	Neutral to perceive	Important to perceive
Number of perceived features of BD existing in the perceived spatial elements in all cases	Between 0–31: Equivalent to 0%–49% perceived features and representing the low-value perception of BD features	Equal to 32: Equivalent to 50% of perceived features representing the neutral-level perception of BD features	Between 33–64: Equivalent to 51%–100% of perceived features and representing the high-value perception of BD features
The level of importance of the perception of elements/features/number of perceived features	Not important to perceive	Neutral to perceive	Important to perceive
The level of ease of perception of the BD elements/features	Not easy to perceive	Neutral to perceive	Easy to perceive

In circumstances of more difficult perception, the results revealed:

- The low number of participants who perceived features of BD, and the high number of perceived features of BD, existing in the perceived spatial elements in all cases or vice versa; the level of ease of perception of the elements/features was considered not important and not easy to perceive.
- The neutral number of participants who perceived features of BD, and the high number of perceived features of BD, existing in the perceived spatial element in all cases or vice versa; the level of importance of the perception of the elements, features, or number of perceived features was determined to be important, and the importance of the perception level of the elements or features is considered easy.
- The neutral and low numbers, respectively, of perceived features of BD existing in the perceived spatial element in all cases or vice versa; the level of importance of the perception of the elements/features/number of perceived features was determined not to be important, and the perception level of the elements/features/level of importance is defined as not easy (Table 6).

Table 6: Data Analysis of the Ease of Perception of BD Elements/Features

Number of participants who perceived features of BD existing in the perceived spatial element in all cases	A low number of participants perceived features of BD existing in the perceived spatial element in all cases	A high number of participants perceived features of BD existing in the perceived spatial element in all cases
The level of importance of the perception of the elements/features/number of participants who perceived	Not important to perceive (−)	Important to perceive (+)
Number of perceived features of BD existing in the perceived spatial element in all cases	A high number of perceived features of BD exists in the perceived spatial element in all cases	A low number of perceived features of BD exists in the perceived spatial element in all cases
The level of importance of the perception of the elements/features/number of perceived features	Important to perceive (+)	Not important to perceive (−)
The perception level of the elements/features/level of importance of perception of the elements/features	Not easy to perceive (−)	Not easy to perceive (−)

In the third stage, the opinions and perceptions of the participants regarding BID elements/features and the inclusion of elements from nature in the design of their residential environment were analyzed.

The yes/no questions (Q1, Q2, and Q5) were examined based on the percentage of responses. However, when interviewers named things that remained in their memory/caught their attention from the space designed for their apartment (Q3), the responses were analyzed based on the following considerations:

- All named things remained in their memory/caught their eye from the spaces designed for their apartments.

- All named things were considered perceived spatial elements, representing important BD elements/features by default.
- The importance of BD elements/features corresponded to the importance of the perceived spatial elements.
- The importance of the perceived spatial element varies with the frequency of naming things:
  - The most important perceived spatial elements were named according to the highest number/percentage of interviewees (50%–100%).
  - Many participants (10%–40%) named important perceived spatial elements.

Regarding (Q4), the arrangement of the elements that the interviewees wanted to have in their living room design in reality (in the future) was analyzed according to the following considerations:

- The classification of spatial characteristics from one to seven (accessories, materials, colors, designs of furniture, floor, ceiling, and walls) was based on the preference of the highest number of participants per percentage of interviewees.
- Each spatial characteristic involved some BID features as per the matrix (see Appendix D).

Results and Discussion

To identify the most important visual elements/features of a BD, the levels of visual perception of the elements/features within the interior environment (living room) were determined, and the results were derived as explained next.

From Observations Made When Participants Wore VR Headset

Focusing on the visual aspect of the participants' interactions with the design while wearing the VR headset, the following observations were made:

- Ninety percent of the participants showed body movement in space but not very intense movements, 40 percent showed no change in direction in the path of their movement, and 10 percent could not move because they were older (57 years) and had health problems.
- Focusing on head movement, the results showed that 60 percent of the participants moved their heads in different directions (upward, downward, right, and left). Among the others, 20 percent moved their head less in the upward direction and 20 percent moved their head less in the downward direction.

However, when focusing on the participants' impressions of the design (comments at first sight, body movement in the void, and head movement), the following results were observed:

- Ninety percent of the participants talked about their impression of BD using positive expressions ("very beautiful," "I like the exploitation of every wall," "very easy on the eye," "movement is fast," "accurate," "easy," "like nature," "the colors are amazing," "is this my house?" "dumbfounded," "nice," "it's sweet," "wow!" "gorgeous," "beautiful details," "the details are crazy," "wish it was like that," etc.). C9 and C10 requested redesign.
- Of all the participants, 40 percent expressed their views regarding the VR technology (C7: "How can I walk? I have to move slowly so I do not feel dizziness," C8: "Can I walk? Oh, I can see from all sides," etc.)

Focusing on difficulties, we noted that some participants needed glasses because of a vision problem: the physical space around the VR activity needed to be clear for some to prevent collisions; one older participant could not stand, and some felt dizzy when wearing the glasses or developed headaches.

From the number of participants who perceived features of BD existing in the perceived spatial element in all cases, the following results were obtained:

- All the participants perceived a high percentage (>50%) of the BD features included in the design.
- The lowest (56.2%) and highest (84.37%) percentages of perceived features of BD existing in the perceived spatial element represented the perception of thirty-six and fifty-four out of sixty-four elements, respectively.
- Of all the participants, 40 percent (C3, C4, C8, and C9) mentioned all the features (100%) that were included in the design (sixty-four).

For environmental features:

- All participants (100%) touched on the characteristics of plants, colors, animals, and natural materials.
- Of all the participants, 90 percent perceived fire.
- Of all the participants, 80 percent mentioned "fountain" in reference to the water element.

For environmental features, the level of importance of the perception of those features (plants, colors, animals, natural material, fire, and water) was considered high, and the perception of these elements/features was defined as easy.

Overall, all the participants perceived a high percentage of natural shapes and form elements included in the design elements:

- All the participants perceived the attribute of shells and spirals and biomimicry.

- All the participants perceived the tree and columnar support attributes, except for C2, who referenced them in only one of the included space elements, reflecting their importance.

Most participants (80%) perceived the botanical motifs, except for C7 and C10, who referred to them in only one of the listed spatial elements, which reflects their importance.

The importance level of the perception of these features (e.g., shells and spirals and biomimicry, tree and columnar supports, botanical motifs) was considered high, and their perception was defined as easy.

- Of all the participants, 60 percent identified the attribute of egg, oval, and tubular forms in only one spatial element, which reflects the low importance of perception and is defined as not easy to perceive.
- Of all the participants, 70 percent perceived the feature of shapes resisting straight lines in the various spatial elements (between four and six out of seven), which reflects its importance level of perception.
- Of all the participants, 80 percent referred to the simulation of natural features and biomorphy in the various listed spatial elements (between three and five out of six), which reflects their importance as easily perceived features.
- Only 30 percent of the participants referred to arches, vaults, and domes in all listed space elements, reflecting their lack of importance. Hence, they are not easily perceived.

Nearly 60 percent of the participants did not mention natural light from the window, which reflects the difficulty in perceiving this feature and considering lighting as a necessary element that is self-evident in the interior space. The focus is not as much on its presence as on its absence.

From the Semi-Structured One-on-One Interviews after the Experience

Q1 to Q2

By examining the nature of the participants' answers on their opinion about BD applied in their living room, we noted that 90 percent of the participants liked the living room after it was redesigned, except for C9, who remained neutral. However, 100 percent of the participants said that the redesign had a positive effect on their psyche. Some participants (40%) expressed feelings of visual comfort and calmness, particularly simplicity and beauty. Others (60%) emphasized the importance of natural elements in the interior.

Q3

In identifying the sample's perception of design changes through the included BD elements/features by naming things that remained in interviewees' memory/that caught their eye from the space designed in their apartment, the results are as follows (see Table 7):

- The most named visual spatial element was color (e.g., color of the window curtain, sofa/furniture color) by 70 percent of the interviewees.
- Fountain, waterfall, and wallpaper were named by 60 percent of the interviewees.
- These spatial elements represent color, water, natural materials, arches, vaults, domes, and biomimicry. These BD features were considered the most perceived features.

However, only 10 percent of the interviewers named shapes, doors, wooden doors, wooden walls with arches, plants, and light. Only 20 percent of the named accessories were placed on the table, tables, pillows with animal drawings, and wooden parquet.

While biophilic features, animals, natural materials, tree and columnar supports, shells and spirals, shapes resisting straight lines, color, botanical motifs, and biomimicry were all important in design changes in the sample's perception, they caught the attention of only a small percentage of the interviewees.

Table 7: Sample's Perception of BD Elements/
Features on Interiors through Naming Spatial Elements

Biophilic Design	*Biophilic*	1. Environmental features	1. Environmental features 2. Natural shapes and forms	1. Environmental features 2. Natural shapes and forms	1. Environmental features 2. Natural shapes and forms	1. Environmental features 2. Natural shapes and forms	2. Natural shapes and forms	1. Environmental features 2. Natural shapes and forms	2. Natural shapes and forms	2. Natural shapes and forms	1. Environmental features	1. Environmental features	3. Natural light	
	Biophilic Features	1.3. Water	1.4. Color 2.1. Botanical motifs 2.6. Arches, vaults, and domes	1.5. Animals 1.6. Natural materials 2.3. Animals	1.6. Natural Materials 2.2 Tree and columnar supports 2.4. Shells and spirals 2.7 Shapes resisting straight lines	1.6. Natural materials 2.6. Arches, vaults, and domes	2.10. Biomimicry	1.4. Color 1.5. Animals 1.6. Natural materials 2.1. Botanical motifs 2.3. Animals 2.6. Biomimicry	2.4. Shells and spirals 2.5. Egg, oval, and tubular forms	2.2. Tree and columnar supports 2.4. Shells and spirals 2.7. Shapes resisting straight lines	1.5. Color	1.2. Plans	3.1. Light and space	1.6. Natural materials
Spatial Elements	Accessories		Wall	Accessories (sculpture)	Furniture	Door	Wall	Accessories	Accessories (light)	Furniture	Accessories (furniture, walls)	Accessories	Window	Flooring
Participants Expression	Fountain, waterfall		Wallpaper	Accessories above the table (vase)	Tables	Shape door, wooden door	Wooden wall with arches	Pillows with animal drawings	Chandeliers	Sofa/furniture	Color in general (e.g., color of the window curtain, sofa/furniture color	Plant	Light	Wooden parquet-
Number of Participants	6		6	2	2	1	1	2	3	4	7	1	1	2

Q4

The most important elements that the participants wanted to achieve in the design of their living room in the future by including elements of nature were as follows:

- Of all the interviewees, 40 percent mentioned design walls as their first preference to achieve in the design. Design walls involve BID features such as color, botanical motifs, shapes resisting straight lines, simulations of natural features, and biomorphy and biomimicry. The interviewees highly solicited color paintings, paper walls with motifs, and surfaces treated with wooden shapes.
- Of all the interviewees, 50 percent wanted design flooring as the second preference in achieving the design. Flooring involved natural materials as BID features.
- Of all the interviewees, 40 percent wanted a designed ceiling as their third preference in achieving the design. The ceiling design involved BID features such as egg, oval, and tubular forms and arches, vaults, and domes.
- Of all the interviewees, 40 percent wanted colors as their fourth preference to achieve the design. However, 50 percent of the interviewees wanted materials as their fifth preference

to achieve the design. The materials involved natural materials in furniture, flooring, wooden windows, doors, and accessories (sculptures, carpets, pillows, etc.).

- Of all the interviewees, 30 percent wanted furniture as their sixth preference in the design. The furniture involved color, natural materials, tree and columnar supports, shells and spirals, and shapes resisting straight lines as BID features.
- Of all the interviewees, 80 percent wanted accessories as their seventh preference to achieve in the design. The accessories involved carpets, pillowcases, fountains, lights, sculptures, candles, shells, paintings, and plants.

In general, the interviewees focused more on fixed spatial elements (design wall, flooring, and ceiling) than on movable elements (accessories and furniture).

Q5

Regarding the inclusion of natural elements in designing the residential environment, all interviewers affirmed that it was necessary. Some mentioned that using natural elements made the space beautiful, calm, or visually comfortable. However, two interviewees (C4 and C9) specified that it was necessary to harmonize natural elements and choose appropriate spatial elements to place them in suitable positions.

Most Important Reference Guidelines for Employing BD Elements/Features

To achieve the quality of life by providing the least positive impact on the psyche of users, it is usual for the level of visual perception of the visual elements/features of BID to vary according to the situation and characteristics of the sample. However, studying the visual aspects of these elements/features is important because their role, directly or indirectly, improves the daily lifestyle of interiors and positively impacts well-being.

Regardless of the diversity and multiplicity of the visual elements/features of BD in the field of interior design, studies (Putri and Pawestri 2020) have proven the existence of eleven visual BD strategies. Adapted to our framework, these spatial elements included seventeen BD features classified as fixed (e.g., walls, ceiling, and flooring) and movable (e.g., furniture and accessories) spatial elements.

The results showed that 90 percent of the participants expressed appreciation for the design and liked the living room after redesigning and that all of them declared that the redesign positively affected their psyche. All interviewees affirmed that it was necessary to include natural elements in the design of their residential environments.

In the context of efforts to improve the daily lifestyles of individuals and society, the design of living rooms plays an important role in integrating the natural aspects of interior design and supporting the well-being of individuals and families.

In this context, several guidelines have been generated to develop concepts for the ease of integrating visual BD features into interiors:

- Choosing colors in line with the design of the spaces, decoration, and natural shapes
- Providing accessories representing animals, water, and fire, which can be observed and changed as needed
- Adopting the characteristics of natural shapes and forms in designing visuals in space (surfaces, furniture, accessories, etc.)
- Designing walls by incorporating motifs of nature, colors, and natural materials
- Including different motifs of nature in the designs of accessories for wall surfaces, furniture, etc.
- Employing natural materials in design
- Providing plants for indoor spaces
- Providing a window to take advantage of the daylight and the landscape
- Harmonizing between the natural elements and choosing appropriate spatial elements to place in suitable positions

Conclusion

This study focused on user perceptions of implicit visual BD features included in fixed (e.g., walls, ceilings, and flooring) and movable (e.g., furniture and accessories) spatial elements. Most previous BD-related studies focused on explicit visual BD features in architectural spaces. In terms of the most important elements/features of a BD living room that are visually easy to perceive, all participants perceived a high percentage (>50%) of the BD features included in the design.

In terms of environmental features, the level of importance of the perception of plants, colors, animals, natural materials, fire, and water was considered high, and such a perception was defined as easy. Nevertheless, color, water, and natural materials were considered the most perceived features because the interviewees named them when they were asked to name things that remained in their memory/that caught their eye from the space designed in their apartment.

In terms of the natural shapes and forms of elements, the level of importance of the perception of shells, spirals, and biomimicry, tree and columnar supports and botanical motifs, shapes resisting straight lines, and simulation of natural features and biomorphy is considered high, and the perception of these elements/features was defined as easy.

Nevertheless, egg, oval, and tubular forms and arches, vaults, and domes reflected a low importance of perception and were not easy to perceive. Although arches, vaults, and domes, in addition to biomimicry, were mentioned as important in the interviews, they were not part of a spontaneous description. In terms of the light and space element, natural light through the window reflected the low importance of perception and was not easily perceivable.

Proposals that could develop the concept of BD within residential environments and activate psychological functions were also inferred from the participants' responses. For instance, the interviewees highly solicited color paintings, wallpaper with natural motifs and surface treatment, and shapes. Furthermore, they preferred natural materials in the design of furniture, flooring, wooden windows, doors, and accessories (sculptures, carpets, pillows, etc.) to improve their visual BID. Furthermore, furniture design fundamentally implies color,

shape, and natural forms (i.e., tree and columnar supports, shells and spirals, shapes resisting straight lines, egg, oval, and tubular forms, and arches, vaults, and domes).

As this study was preliminarily based on implicit visual BD features included in spatial elements, future studies should increase the number of cases or vary the factors affecting the perception of BD elements/features in the interior environment (gender, age, housing type, etc.). They should include people from various areas of Saudi Arabia (North, South, East, and Central). Alternatively, such studies can analyze similar themes between distinct cultural contexts or highlight differences between cultural settings in different cultural contexts at the oriental or occidental level. To familiarize itself with deeper consequences, future research should extend the method to diverse spaces in domestic situations instead of confining it to living rooms. Alternatively, future studies can consider various types of places (e.g., cafés and offices).

However, when it comes to adopting VR technology, future research should use the most advanced VR technology that enables participants to walk in the interior. Our approach is a rapid alternative for exploring implicit visual BD features in interior design. The results of this study are expected to serve as a reference point for designers who apply BD in residential spaces and guide them in choosing the most important elements of BD that are easily perceptible to users.

Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Appendix A

https://drive.google.com/file/d/10tjKnmtDyJ-loP5vdOr9zxZjJlpMg62g/view?usp=drive_link

Appendix B

https://drive.google.com/file/d/1fFDUQ31UB5x-Tc2gpvPO1zsxaP3pz_ay/view?usp=sharing

Appendix C

https://drive.google.com/file/d/1t-DkL0mEpb4rvl9SBN-6h22pHUlasduZ/view?usp=sharing

Appendix D

https://drive.google.com/file/d/1vXpEjZbJ953k9VyqEkuLd_R_NCXopyF4/view?usp=sharing

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