SPACIOUSNESS AND EMOTIONAL RESPONSES TO CURVED SPACE BOUNDARIES

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ABSTRACT

Properties like size, light, texture and color unite to make a composition to form a space. Various properties that affect people's attitudes and emotions towards a space are critical issues that have an impact on people's life quality. Quality of life is a concept related to cognitive and affective assessments that are based on the matching of one's expectations with the properties of physical space. Therefore, an interior architect design spaces while concentrating on the properties of that space. The study explores the perceived spaciousness of a 3D virtual model with curved boundary types using a Head Mounted Display (HMD) to find out the influence of specific space properties (size, light, texture, and color) and to associate the relationship between spaciousness and emotional responses.

The perceived spaciousness level of two-curved boundary types (horizontal and vertical) of interior spaces was analyzed with a HMD related to one of the specific properties varying in two levels of intensity; high and low. Sixteen different physical property spaces were designed to measure. Total of 128 participants assessed their emotional responses corresponding to three variables (pleasure, arousal, and dominance). The survey included both ranking and open-ended questions for each setting. According to the ranking results, perception of spaciousness was positively related with the curved boundaries and large size, bright light, lateral texture, and cool color of the spaces. In all specific properties, more spaciousness was perceived firstly in curved horizontal than vertical boundaries. Besides, curved boundaries evoked pleasing, satisfying, relaxed and happier emotional responses in perception of spaciousness of individuals. Also, according to the open-ended questions, three multiple-choice questions were provided in order to have an overall view of behavioral intention that were focused on time span, enjoyment and feel friendly level. As a result, the behavioral intentions (approach-avoidance behaviors) are different in

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the four settings in terms of specific properties. It is concluded that different, intensities of space properties could be used to control the amount of spaciousness level in interiors. Also, these levels provoke strong differences in emotional responses of individuals. Besides, designers and architects could use the findings to manipulate curvilinearity of the boundaries with many specific properties to provide a high level of perception of spaciousness.

Key words: Spaciousness, Emotional Responses, Curved Space Boundaries, Virtual Reality

1. INTRODUCTION

Life quality in an environment is affected by the people's attitude and evoked feelings that are the results of physical space properties (Elver 2018). Previous theoretical and experimental studies in environmental psychology showed that space perception and evoked feelings are the essential components of spaces. This study explores the perception of spaciousness with respect to specific physical properties and supports the idea with emotional responses as components of feelings. Although numerous studies are carried out in order to analyze the impact of perception on spaciousness, those were limited to one boundary type or one specific property and few emotional aspects. Thus, this study aims to fill this gap while analyzing the impacts of boundary types (curve horizontal-vertical) and specific properties (size, light, texture and color) on perception of spaciousness with the related emotional responses.

2. SPACIOUSNESS IN THE ENVIRONMENT

Humans spend approximately 90% of their time indoors with enclosure and they interact intimately with these spaces (Vartanian et al. 2013). Main components of a space are perceived, evaluated and evoke feelings in humans towards that space (Gifford 2002). Space has both psychological and physiological influences on and interactions with people. Environments that do not provide sufficient space are ambient stressors and, thus they should be avoided, and if they are unavoidable, their effects should be mitigated as much as possible (Stamp 2011).

Spaciousness is also investigated with respect to human behavior both in built and natural environments. This study mainly focuses on the built environment and the literature is investigated within this framework. Bharucha-Reid and Kiak (1982) analyzed the human perception of rooms (spacious, adequate, well-arranged) that varied in floor area from 4.7 to 22 square meters. They reported that the larger room is evaluated more positively than the smaller room. Also, research on spaces with emphasis given to environmental feelings reported that people prefer larger or more open spaces to smaller or more constricted ones (Ozdemir 2010).

Some previous studies reported general assessments of humans based on spaciousness. However, in some cases, people also could prefer smaller or more private spaces according to their specific needs. Perception and measurements of the environmental properties could be determined by various factors (Nasar 2008). Spaciousness could be measured by the length, width, and height of a space, but holistic judgments of spaciousness could rely on more to one of these measurements compared to the others (Stamp 2011).

One of the fundamental human needs is having enough space for living and spacious atmosphere for both physical and psychological order (Stamps 2009). Several physical properties of a space could affect the human perception of spaciousness in various ways. One of the effective aspects of the physical properties is the boundary of a space and its' properties. The space boundary is a spatial enclosure which is surrounded with walls in order to prevent free ingress or egress (Stamp 2010a; Stamp and Krishnan 2006). Spaciousness then becomes the apparent size of the region within the boundary.

The physical characteristics of an environment, the human and the conducted activities in that environment are defined by people-place relationships (Dazkır and Read 2012). In this study, as an environmental characteristic, the physical properties of the boundary are related to the sense of spaciousness. The boundary properties could change spatial human perception in the environment. These changes occur, like an illusion conducted by the architects, according to the situation of the space and human needs (Bokharaei and Nasar 2016; Sadalla and Oxley 1984).

2.1. Environmental Emotions

Physical properties of an environment could evoke an emotion generated towards the environment. Many studies analyzed people and environment relationship with respect to the emotional responses (Franz, Von der Heyde and Bülthoff 2005) or the built environment in terms of its' effects on human emotional responses (Bokharaei and Nasar 2016; Mehrabian and Russell 1974; Russell 1992; Russell and Mehrabian 1977; Russell and Pratt 1980; Russell, Ward and Pratt 1981). Besides many researchers investigated the taxonomies of feelings while using empirical protocols (Mehrabian 1995; Mehrabian and Russell 1974; Osgood, Suci and Tannenbaum 1957; Osgood, May and Miron 1975).

Russell and Mehrabian (1974) defined three dimensions of emotions, which are pleasure (pleasant-unpleasant), arousal, and dominance, that summarize the emotional responses to all types of environment. Furthermore, Mehrabian and Russell (1974) explained that a feeling is described as projection of pleasure, arousal and dominance. According to their theory, pleasure is demonstrated through facial gestures (such as smiling and frowning) and by scales (such as annoyed-pleased, and happy-unhappy, bored-relaxed, unsatisfied-satisfied, melancholic-contended, despairing-hopeful). Arousal is indicated by human activities and alertness (such as skin responses) and by scale (such as unaroused-aroused, calm-excited, sluggish-frenzied, dull-jittery, sleepy-wideawake, relaxed-stimulated). Dominance is indicated by scales (such as in control-cared for and autonomous-guided) (Mehrabian and O'Reilly 1980; Stamps 2010b).

Later, Russell and Mehrabian (1977) conducted a research using verbal reports and they concluded that the emotion-eliciting quality of an environment affects people's approach toward that environment. In addition, Russell (1992) created affective appraisal in order to measure how people evaluate their built environments. According to the Russell's (1992) theory, affective quality is the determinant of human response to environment.

2.2. Emotions and Curved Space Boundaries

Several architectural studies focused on the curved space boundaries with the related feeling components. Initially, Alp (1993) conducted an experimental study with rectangular, triangular and circular (curvilinear) geometric configurations for architectural spaces and analyzed their emotional effects. The findings showed that all three configurations elicited highly significant emotional responses. Especially circular (curvilinear) space had higher ratings than rectangular and triangular spaces.

The aim of Madani Nejad's (2007) study was to investigate the emotional effects of curvilinear forms in interior space settings where the architectural forms gradually changed from being fully rectilinear to curvilinear. The qualitative and quantitative findings demonstrated that curvilinear form tends to make the observers feel safer, and perceive the space to be more private and pleasant, and less stressful.

Then, Dazkır and Read's (2012) research study focused on pleasure and approach reactions towards rectilinear and curvilinear stimulated interior settings. Their study is related to furniture forms and their influence on people's emotional responses towards created 3D interior settings. As a result of the study, curvilinear forms were found to be significantly stronger and more pleasurable than rectilinear forms. With regard to emotional judgement, the study indicated that curvilinear settings showed higher amounts of pleasant-unarousing emotions that contain the feelings of relaxation, peacefulness and calmness.

Later, Vartanian et al. (2013) analyzed three architectural variables, which were curved versus rectilinear contours, openness and ceiling height in beauty-judgement and approach-avoidance behaviors. This research suggested that, people were more likely to judge curvilinear spaces as more beautiful than rectilinear spaces, and that judgment of beauty for curvilinear spaces was supported by emotion, human behavior and brain functions. The authors inferred their results to indicate that, in architecture, sharp contour might not serve as an early warning signal for potential dangers, as it might elsewhere.

Furthermore, Shemesh et all. (2016) investigated the human reactions to square, round (domed), sharp-edged and curved spaces. The findings related to the virtual reality (VR) environment experience revealed that non-design students had a tendency to prefer curvy shaped spaces and design student had a tendency to prefer sharp-angled spaces. Findings based on people's mental reactions encoded with an electroencephalogram showed that participants perceived symmetrical space differently from asymmetrical space with unconscious brain ability. Also, the results pointed to a difference in people's mental reactions towards different geometric forms of space. Emotional responses are the main components of feelings that provide a relationship with this study.

Virtual reality technologies enable users to immerse virtually in spaces. Defining the boundaries of an architectural immersive environment imitates that of a visual living space. Therefore, it enables to walk through space as if one were in the existing location. Implementation of properties like size, light, texture, and color to the boundaries of that space help to create the viewer's sense of place within the environment, enriching the experience by enhancing engagement and meaning for the viewer more than a three-dimensional space is. Making sense of place within a virtual environment must draw attention to the sensations, feelings, thoughts and emotions of viewers of that space. Executing this within a space includes employing recognizable elements within the design of boundaries of the surrounding environment. Virtual environment boundaries should be carefully designed to achieve the most significant understanding and knowledge gain for the viewer, regarding the spatial world. By creating virtual environment, two conducted research questions are analyzed in this study.

Research Question 1 **(RQ1)**: How do the horizontal and vertical curved boundaries influence peoples' perceptions of spaciousness with emotional responses under specific properties of space (size/ light/ texture/ color)? Research Question 2 **(RQ2)**: Does horizontal or vertical curvilinear boundaries have a more influence on the perceived spaciousness?

3. METHOD

3.1. Environmental Stimuli and Procedures

In this research, the perceived spaciousness level of two-curved boundary types of interior spaces are analyzed; namely, curved Horizontal Boundary (HB) and curved Vertical Boundary (VB). HB space is bounded by four walls and the boundaries of each wall are connected with horizontal concave connections. There is no 90-degree edge in horizontal plane of the space as there are in standard room connections. VB space is bounded by four walls and the boundaries of each wall are connected to ceiling as vertically concave links. There is no 90-degree connection of vertical walls and ceiling as standard space connections.

The perceived spaciousness includes two-curved boundary types (HB and VB) of interior spaces and each boundary type involves four specific properties (size, light, texture, and color) of the surrounding surfaces that are composed of two levels of intensity; high and low. The four specific properties namely as; size (small-S and large-L), light (dim-D and bright-B), texture (longitudinal-LT and lateral-LR), and color (cool-C and warm-W).

First hypothesis **(H1)** is that there is no difference in perception of spaciousness between boundary types (HB and VB), and between each boundary-specific property (S/L, D/B, LT/LR, C/W) and the interraction between boundary types and each specific property . Furthermore, second hypothesis **(H2)** is that emotional responses based on the curved boundary types (HB/ VB) are a function of spaciousness. Besides, third hypothesis **(H3)** is that emotional responses based on the specific properties (size/light/texture/color) of the curved boundaries have a positive influence on the perception of spaciousness in interior spaces. The study variables shown in Figure 1.

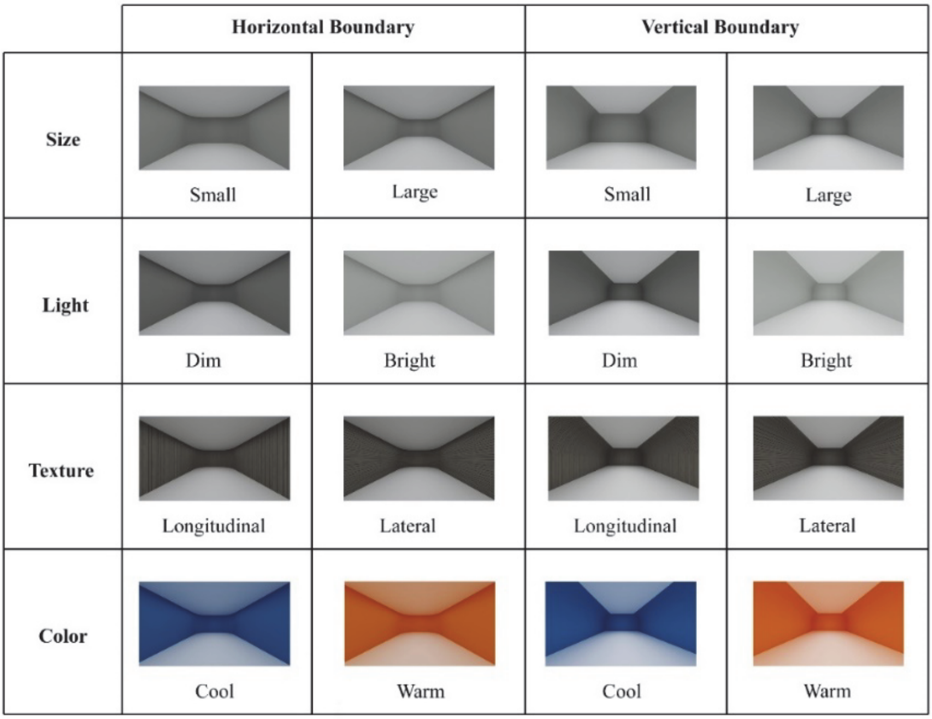


Figure 1. Study variables and their visualizations

3.2. Instruments

Each participant rated one set of survey that consists of four virtual interior spaces with two-curved boundary types (HB and VB) and having only one of the specific properties (size/light/texture/color). The spaciousness level of four 360-degree spaces was determined by using a Gear VR, Head Mounted Display (HMD), equipment (Samsung SM-R325 Gear VR). Visual stimuli were showed, with the same layouts, that there were no materials and openings in the created space in order not to affect the perception of specific property with boundary type.

All spaces were designed to have the same size (4.5 m in width, 9 m in length and 3 m in height), and the lighting was non-directional and created equal illumination in all parts of the space. In this study, both spaces in each specific property have the same floor area (40.5 m2). Moreover, based on the study of Hopkins, Kagan, Brachfeld, Hans and Linn's (1976), the moderate curve (4 ½ in.) was chosen as the curvature of the horizontal and vertical boundaries. Also, the movements of the participants were based on egocentric frame of reference (i.e. one's body) during simulations in virtual environments (Sancaktar and Demirkan 2008).

This procedure was repeated for all curved boundaries (HB and VB) for size (S-L), light (D-B), texture (LT-LR) and color (C-W) independently in four experiment sets. The created 3D 360-degree simulations were experienced using Gear VR by participants. Also, participants answered all questions in virtual environment. Using VR test is an advantage to compare using immersion level test because this does not allow interruption in simulation.

Firstly, the participant identified the spaciousness level for an interior space. Spaciousness of the interior space was rated for one of the specific properties with the direction of the curved connections of the boundary type. The 5-point Likert scale is used to identify the immediate responses of participants' perceptions on four interior spaces. One refers to the lowest level (extremely negative) and five shows the highest level (extremely positive) of perceived spaciousness.

Then the perceived spaciousness levels were assessed and associated with the relevant emotional responses' adjectives. The selection of relevant adjectives ensures appropriate methods of measurement for the effect of curvilinear architectural form on human emotional responses (Dazkır and Read 2012). The words chosen for emotional responses set are adapted from Mehrabian and Russell (1974) and Dazkır and Read (2012). The emotional responses consist of two variable components and these are as follows: Pleasure Variables (PL) and Arousal Variables (AR).

Centering on the more specific impressions, the second stage of the study obtains the ratings of twelve items of emotional responses from 12 pairs of bipolar adjectives with semantic differentials with an added "neutral" between each pair. For the sets from one through twelve, negative preference is noted as the first set of words, while positive preference is the last word.

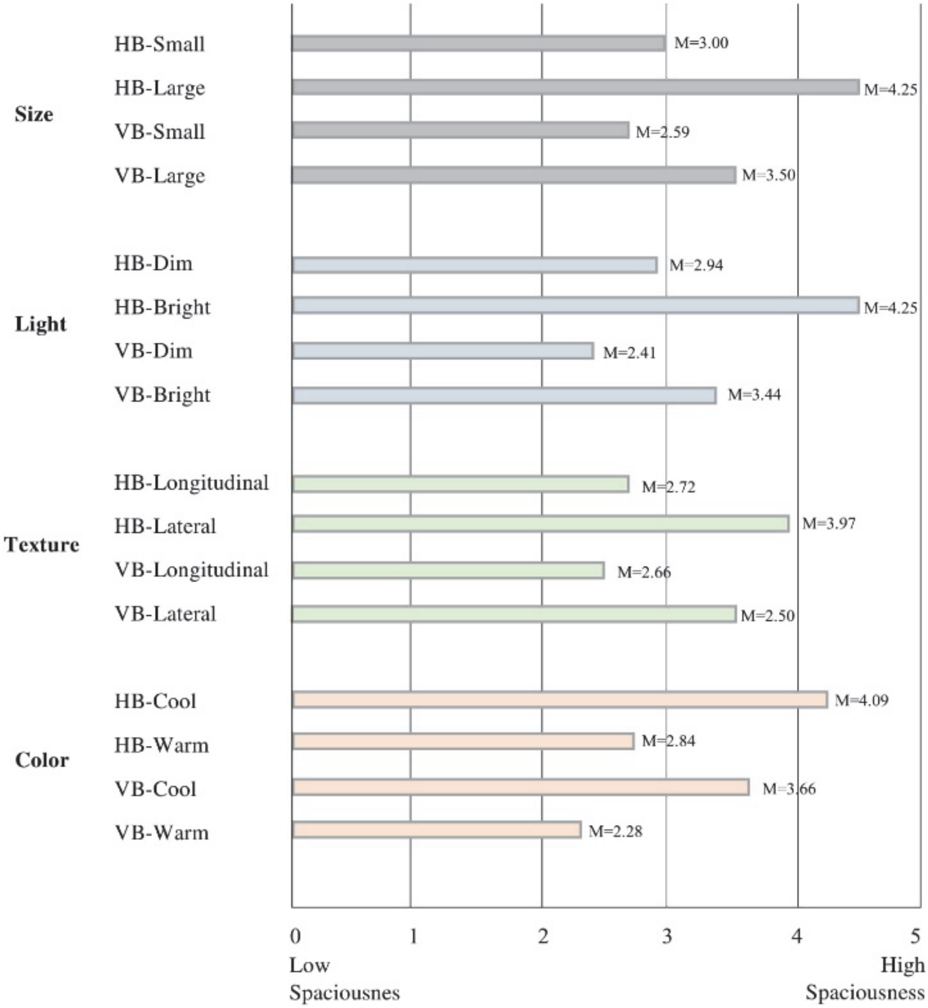
3.3. Participants

The participants are chosen on voluntary basis by stratified sampling among the students of I.D. Bilkent University at Ankara, Turkey. Ishihara electronic color blindness test is used to analyze whether the 134 participants have an appropriate color perception or not before the experiment. Total of 128 eligible graduate and undergraduate students, 64 males and 64 females participated in the experiment from the social science and design departments. The age range of the participants was 19 to 29 years. All the participants provided the written informed consent form and the Ethics Committee of I.D. Bilkent University approved this study (No: 2018_01_18_04).

4. RESULTS

4.1. Perception of Spaciousness

Considering each specific property, in size L, in light B, in texture LR, and in color C spaces were considered to be more spacious as seen in Figure 2. In all specific properties, more spaciousness was perceived in HB spaces and it was followed VB spaces. It is concluded that although they have the same preferred specific property, HB spaces are perceived more spacious compared to VB spaces.



Note. **HB** = Horizontal Boundary and **VB** = Vertical Boundary

Figure 2. Mean scores for perception of spaciousness in size, light, texture and color

4.2. Boundary Types, Specific Space Properties and their Interactions

Four different two-way independent variance analysis (ANOVA) were conducted in order to understand the relationship between curved boundary types (HB and VB) and four specific properties (size, light, texture, and color) of interior spaces. For size properties, A two-way unrelated ANOVA showed that significant effects on spaciousness were obtained for curved boundary types ($F(1,124)=8.86$, $p= 0.004$, partial $\eta^2 = 0.067$) and size property ($F(1,124)=30.81$, $p < 0.0005$, partial $\eta^2 = 0.199$), but not for their interaction ($F(1,124)=0.78$, $p=0.378$, partial $\eta^2 = 0.006$). Also for light properties, significant effects on spaciousness were obtained for curved boundary types ($F(1,124)=16.98$, $p < 0.0005$, partial $\eta^2 = 0.120$) and light property ($F(1,124)=51.67$, $p < 0.0005$, partial $\eta^2 = 0.294$), but not for their interaction ($F(1,124)=0.74$, $p=0.390$, partial $\eta^2 = 0.006$). For texture properties, the test indicated that significant effects on spaciousness were obtained for texture property ($F(1,124)=29.65$, $p < 0.0005$, partial $\eta^2 = 0.193$), but not for curved boundary types ($F(1,124)=1.91$, $p= 0.170$, partial $\eta^2 = 0.015$) and for their interaction ($F(1,124)=1.116$, $p=0.290$, partial $\eta^2 = 0.009$). Also for color properties, significant effects on spaciousness were found for curved boundary types ($F(1,124)=10.48$, $p= 0.002$, partial $\eta^2 = 0.078$) and color property ($F(1,124)=72.24$, $p < 0.0005$, partial $\eta^2 = 0.368$), but not for their interaction ($F(1,124)=0.164$, $p=0.686$, partial $\eta^2 < 0.0005$).

Considering each specific property and the curved boundary type independently, it was found that there was a significant impact of boundary type; and size, light, and color properties on spaciousness except the texture property of the interior space boundary. First hypothesis **(H1)** was that there is no difference in perception of spaciousness between boundary types (HB and VB), and between each boundary-specific property (S/L, D/B, LT/LR, C/W). All hypotheses were rejected, except texture specific property (LT/LR) and all interactions between boundary types and specific properties.

4.3. Emotional Responses of Spaciousness

Since statistically analysis showed that there was no effect of the interaction between boundary types and the specific properties of interior spaces on spaciousness, the multiple regression analysis for emotional responses is conducted under two headings as boundary types and specific properties. The items of the emotional responses' dimensions are the independent variables where the perception of spaciousness is the dependent variable.

4.3.1. Based on Boundary Types

It was hypothesized **(H2)** that emotional responses were based on the boundary type (HB / VB) as a function of spaciousness. The results showed that for the size, the highest significant levels was felt as ‘pleased’ (PL) item, for light were felt as ‘pleased’ (PL), ‘relaxed’ (PL) and thought as ‘stimulated’ items, for texture felt as ‘pleased’ (PL), ‘satisfied’ (PL) and ‘happy’ (PL) items and for color as ‘pleased’ (PL), ‘hopeful’ and thought as ‘frenzied’ items.

4.3.2. Based on Specific Space Properties

It was hypothesized **(H3)** that emotional responses were based on the specific properties (size/ light/ texture/color) as a function of spaciousness. The results showed that for the size, the highest significant level was felt as ‘happy’ (PL) item, for light were felt as ‘bored’ (PL) and ‘relaxed’ (PL) items, for texture was felt as ‘satisfied’ (PL) item and for color as ‘pleased’ (PL) item.

Table 1 and 2 shows all the boundary type and specific property for emotional response items. The highest level of adjectives showed with symbols (**).

Table 1. Emotional responses of spaciousness in boundary types

Size	Light	Texture	Color	Emotion Scale		Size	Light	Texture	Color
				Pleasure (PL)					
				Annoyed	Pleased	HB**	HB*	HB	HB**,VB
				Unhappy	Happy	VB		VB**	
				Bored	Relaxed		VB**		
				Unsatisfied	Satisfied		HB	HB**	
				Melancholic	Contended				
				Despairing	Hopeful				
				Arousal (AR)					
				Unaroused	Aroused				
				Calm	Excited				
				Sluggish	Frenzied	VB			HB**
VB				Dull	Jittery				
				Sleepy	Wide-awake				
				Relaxed	Stimulated		VB**		

Note. *Significant at $p<0.0005$ and **Significant at $p < 0.002$ (**HB** = Horizontal Boundary and **VB** = Vertical Boundary)

Table 2. Emotional responses of spaciousness in specific space properties

Size	Light	Texture	Color	Emotion Scale		Size	Light	Texture	Color
				Pleasure (PL)					
				Annoyed	Pleased		D,B		C**
				Unhappy	Happy	S,L*		LR	
	D**	LT		Bored	Relaxed		B**		
				Unsatisfied	Satisfied	S		LT**	
				Melancholic	Contended				W
				Despairing	Hopeful				
				Arousal (AR)					
			W	Unaroused	Aroused	L	D		
				Calm	Excited				
				Sluggish	Frenzied				
				Dull	Jittery				
				Sleepy	Wide-awake				
				Relaxed	Stimulated		D,B		

Note. *Significant at $p < 0.0005$ and **Significant at $p < 0.002$ (S = Small, L = Large, D = Dim, B = Bright, LT = Longitudinal, LR = Lateral, C = Cool, W = Warm)

5. DISCUSSION AND CONCLUSION

This study investigated the relationship between the perception of spaciousness and curved space boundaries with different specific properties of the environment such as size, light, texture, and color. Furthermore, the aim was to associate the relationship between spaciousness and the emotional responses of the participants in a virtual environment. According to the results, perception of spaciousness is positively related with the curved boundaries. However, findings of this study are in agreement with the previous findings that claimed that perception of spaciousness increases with large size (Bokharaei and Nasar 2016; Franz, Von der Heyde and Bülthoff 2005; Stamps, 2009, 2010b) bright light (Bokharaei and Nasar 2016; Stamps 2010a), lateral texture (Bokharaei and Nasar 2016; Sadalla and Oxley 1984; Stamp 2011), and cool color of the spaces. It was also found that the emotional responses support the perception of spaciousness with Pleasure (PL) and Arousal (AR). Curved boundaries evoked pleased, happy, relaxed, satisfied, frenzied, and stimulated emotional responses in perception of spaciousness of individuals. The findings of this study suggested that designers and architects can manipulate curvilinearity of the boundaries with many specific properties to provide a high level of perception of spaciousness.

The design implications for interior designers were developed in detail with the relevant specific properties and curved horizontal boundary types that affect the perception of spaciousness in a high rating. There are some suggestions for further research thet the relationship between curved boundary type and any other geometric form of space boundaries could be tested with these specific properties and emotional responses of the participants could be investigated as well. This study can be repeated by adapting context to virtual reality stimuli. Various interior settings could be tested including residential settings, restaurants, cafes, office environments, classrooms, hospitals, hotels, dormitories, etc.

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