The Impact of Monochrome Virtual Landscapes on Human Perception and Emotion

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Abstract: This study explores the emotional and physiological effects of monochrome and colored virtual landscapes (VL) across natural, artificial, and interior environments. Utilizing VR technology, participants experienced six VL settings, designed in both colored and monochrome formats, to assess their responses through heart rate measurements, emotional evaluations, and time spent in each environment. Results reveal that natural VLs, even in monochrome, promote relaxation and satisfaction, while monochrome artificial environments increase anxiety and discomfort. Colored VLs generally enhance emotional well-being and engagement compared to their monochrome counterparts. These findings offer valuable insights for integrating color and design elements in virtual and physical spaces, with applications in digital therapy, urban planning, and architectural design. The study highlights the potential of VLs to create restorative, human-centered environments and emphasizes the importance of further research into the psychological impacts of virtual design.

Keywords: Virtual landscapes, color perception, emotional response, monochrome environments, virtual reality

1 Introduction

With the rapid expansion of the virtual reality (VR) market, which is projected to grow from 32.64 billion USD in 2024 to 244.84 billion USD by 2032 (FORTUNE BUSİNESS INSİGHTS, 2024), VR is evolving far beyond its gaming origins. IKEA (OZTURKCAN 2020) and Volkswagen (VİRTUAL REALİTY n. d.) already harness design, retail, and healthcare technology, emphasizing its wide-ranging applications. As VR becomes more embedded in various sectors, creative design possibilities are set to expand significantly (BOWMAN & MCMAHAN 2007). The studies of ÖKSÜZ & KIM (2024) and JAHANDIDEH et al. (2023) indicate that even the field of landscape architecture is expanding its design territory towards virtual reality as a virtual landscape (VL). However, to fully realize its potential, especially in environments where every element can be meticulously controlled, we need a deeper understanding of the unique characteristics that differentiate virtual landscapes from the physical (WALSH & PAWLOWSKİ 2002, CAVUSOGLU et al. 2019). One of the powerful design tools in VL is color. Unlike the physical environment, where natural and environmental factors constrain our interaction with color, VL allows designers to manipulate color in ways previously unimaginable, offering both full-spectrum vibrancy and total monochrome experiences.

VL presents the unique possibility of creating a purely monochrome environment where no hue exists – only variations in brightness and texture. Although the impact of color on human psychology has been extensively studied in the physical environment (TANTANATEWİN & INKAROJRİT 2018, ULUÇAY 2018), the understanding of how monochrome environments in virtual landscapes affect human perception and emotions remains limited (GRASSİNİ et al. 2019, RİCHES et al. 2021). This gap is critical because, as virtual landscapes grow in usage, monochrome design styles will likely emerge as a distinct trend, paralleling how monochrom atic photography and art have played crucial roles in aesthetics (GRASSİNİ & RATCLİFFE

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2023). However, little is known about how monochrome VL's might influence human emotions, mood, or cognitive functions. This research addresses this academic and industrial void by exploring how people perceive and respond to monochrome virtual landscapes, potentially offering new design guidelines that could reshape VL's future in multiple domains.

2 Experimental Design

2.1 Experimental Instrument

We created color and monochrome versions of three different virtual environments: a natural environment, an artificial environment, and an interior environment (Figure 1). We used the CIELAB color system for each environment, an international standard (DE L'ECLAIRAGE 2018).

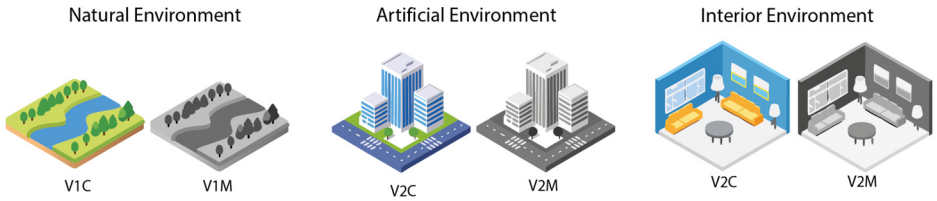

Fig. 1: Representations of the virtual landscapes in the experiment

This color system is a three-dimensional structure, with the axes representing lightness and saturation and the ring representing color (or a*, b* axes for saturation and color).

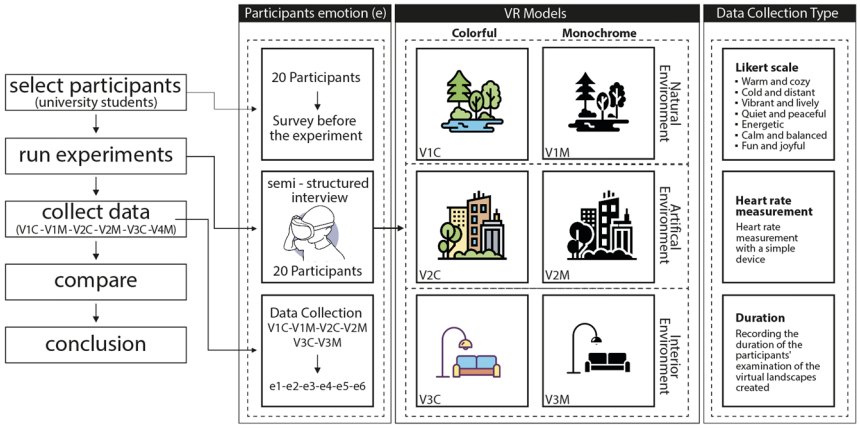

Fig. 2: Overall structure of the experiment

This system provides relatively uniform color scales in terms of lightness (L*) and saturation (Cab*) and an approximately evenly spaced distribution along the color circle (hab*) (SIKLÁNYI 2014). We also used this system because it provides human color perception's whole gamut (range). In this study, as shown in Figure 2, the emotional responses of 20 university

student participants were analyzed across three categories of virtual environments (natural, artificial, and interior) presented in both colorful (C) and monochrome (M) formats. The experimental process began with participant selection and a pre-experiment survey, followed by semi-structured interviews. Data collection involved the use of a Likert scale, heart rate measurements, and the recording of participants' examination duration in Virtual Landscapes. The collected data (e1-e6) were compared based on various emotional responses, providing a comprehensive framework to evaluate the relationship between emotions and the characteristics of virtual environments.

2.2 Experimental Design: VL

The natural environment design (V1C/V1M) (Figure 3), based on biophilic principles, features trees, water elements, and open spaces to promote well-being and stress reduction, created in Blender using calming CIELAB colors. The artificial environment (V2C/V2M) (Figure 3), designed in Unreal Engine 5, reflects modern architecture with urban elements like buildings and roads, emphasizing order and community engagement through neutral tones. The interior environment (V3C/V3M) (Figure 3), also created in Unreal Engine, simulates a modern living room and workspace, balancing relaxation and productivity with ergonomic furniture, decorative elements, and a mix of natural and artificial lighting.

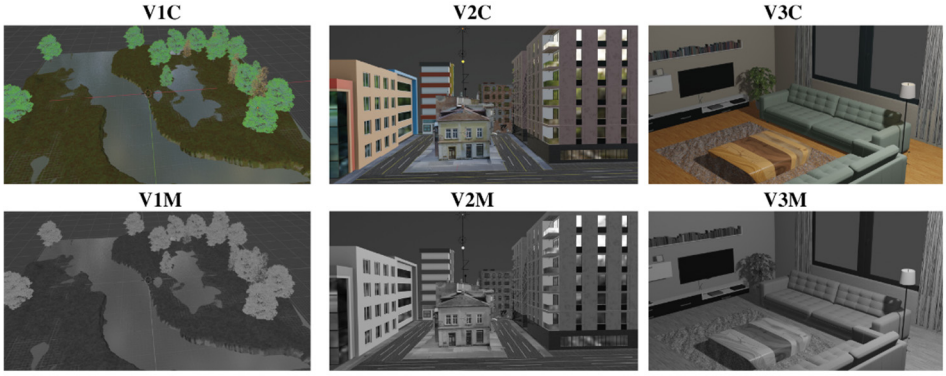

Fig. 3: Designed environment images

3 Participant Selection and Data Collection Procedures

3.1 Survey before the Experiment

This phase consists of two parts. First, a screening questionnaire assessed participants' age, ophthalmological condition, and color blindness status, leading to the random selection of 20 participants. A second questionnaire gathered data on their age, education, occupation, and VL experience.

3.2 Participants

Twenty participants were recruited, with ten males and ten females aged 18-40. This age range was chosen due to the increased incidence of ophthalmological problems in individuals

over 40 (See et al. 1998). Individuals with ophthalmological conditions were omitted, as the study focuses on visual data. The Farnsworth-Munsell 100 Hue test was performed to identify any color blindness. Participants with chronic illnesses or previous adverse experiences in VL (e. g., dizziness, nausea) were excluded.

3.3 Data Collection Methods

Data collection occurred in three stages: semi-structured interviews, heart rate measurements, and recording time spent in each virtual environment. The semi-structured interviews involved participants evaluating each environment on a Likert scale. Emotional well-being was assessed using Warr's questionnaire (MÄKIKANGAS et al. 2007), based on Russell's circumplex model (Russell 1980), which captures basic emotional states effectively (KIM et al. 2017, VIRTANEN et al. 2021). Warr's scale consists of 12 items: six positive emotions (calmness, satisfaction, relaxation, joy, enthusiasm, optimism) and six negative emotions (tension, restlessness, anxiety, depression, gloom, unhappiness) (KUMPULAINEN et al. 2024). A 10-point scale was used, where 0 means 'not at all' and 10 means 'extremely.' Analysis followed KUMPULAINEN et al.'s (2024) four-factor model: Anxiety (Cronbach's $\alpha = 0.83$), Comfort ($\alpha = 0.84$), Depression ($\alpha = 0.74$), and Euphoria ($\alpha = 0.76$). Participants were also asked about creativity and a sense of belonging. Heart rate was measured using the Elite HRV smartphone app, which aligns closely with Polar V-800 heart rate monitor measurements (Chhetri et al. 2022). Changes in heart rate were recorded during experiences in the virtual environments. Participants' time spent in each VL was also noted from the start of their experience until they stopped.

4 Results

The results of this study indicate distinct emotional and physiological differences in participant responses to monochrome and colored virtual environments, with particular emphasis on how the absence of color affects emotional well-being and physiological responses. Below, we present findings for the comparison across all six environments (colored and monochrome) and the analysis among the monochrome environments alone.

4.1 Emotional and Physiological Responses across Colored and Monochrome Environments

Table 1 concisely displays the average relaxation, satisfaction, and anxiety scores and physiological responses across both colored and monochrome environments, helping to visualize each environment type's emotional and physiological impact.

Table 1: Emotional and physiological responses in colored and monochrome virtual landscapes

Environment	Relaxation (0-10)	Satisfaction (0-10)	Anxiety (0-10)	Average Heart Rate Increase (BPM)	Time Spent (minutes)
Colored Natural	7.2	7.0	2.6	3.2	9.4
Monochrome Natural	6.0	5.6	3.0	3.4	8.8
Colored Interior	6.4	6.0	3.2	3.6	8.6
Monochrome Interior	5.6	5.4	3.4	3.4	8.4
Colored Artificial	5.8	5.0	4.0	4.4	7.6
Monochrome Artificial	5.4	4.4	4.4	5.0	7.4

The colored natural environment yielded the highest relaxation and satisfaction, followed closely by the monochrome natural environment, indicating that natural settings foster a calming effect even without color. The colored interior environment also scored relatively high in satisfaction, while the monochrome artificial environment had the lowest scores, suggesting color plays a key role in comfort within artificial settings. Anxiety was highest in the monochrome artificial environment and lowest in the colored natural setting, with the monochrome interior showing moderate anxiety, suggesting that interiors may slightly alleviate monochrome-induced discomfort in artificial environments. Heart rate data followed this trend, with the monochrome artificial environment showing the highest increase, while natural and interior settings saw lower increases. Participants spent the most time in natural environments (colored and monochrome), followed by interior, and least in the monochrome artificial setting, highlighting the greater appeal of natural and interior spaces, even without color.

4.2 Comparison among Monochrome Environments

A focused analysis of the three monochrome environments alone (monochrome natural, monochrome artificial, and monochrome interior) reveals additional insights into how design elements impact emotional responses in the absence of color.

Table 2: Comparison of emotional and physiological responses in colored and monochrome virtual environments

Environment	Relaxation (0-10)	Satisfaction (0-10)	Anxiety (0-10)	Average Heart Rate Increase (BPM)	Time Spent (minutes)
Monochrome Natural	6.0	5.6	3.0	3.4	8.8
Monochrome Artificial	5.4	4.4	4.4	5.0	7.4
Monochrome Interior	5.6	5.4	3.4	3.4	8.4

The monochrome natural environment achieved the highest relaxation and satisfaction, with the interior environment following, suggesting that even in monochrome, natural elements maintain a positive emotional impact, while interiors provide comfort. In contrast, the artificial setting scored lowest in relaxation and satisfaction, amplifying discomfort. Anxiety was highest in the artificial environment and lowest in the natural, while the interior showed moderate levels, highlighting the calming effect of nature even without color. Heart rates were

highest in the artificial setting, aligning with greater discomfort, while lower increases in natural and interior environments reflected lower anxiety. Time followed this pattern, with the most time in natural, moderate in interior, and the least in artificial environments, suggesting that nature and interiors remain engaging even in monochrome.

4.3 Comparison among Average Colored and Monochrome Environments

The average emotional and physiological responses across the colored and monochrome environments are summarized in Table 3. This table provides an average comparison of emotional and physiological responses in colored versus monochrome virtual environments. The colored environments generally resulted in higher relaxation and satisfaction scores, with slightly lower anxiety and heart rate increases compared to the monochrome environments.

Table 3: Average emotional and physiological responses across colored and monochrome virtual landscapes

Environment Type	Average Relaxation (0-10)	Average Satisfaction (0-10)	Average Anxiety (0-10)	Average Heart Rate Increase (BPM)	Average Time Spent (minutes)
Colored	6.5	6.0	3.3	3.7	8.5
Monochrome	5.7	5.1	3.6	3.9	8.2

Participants also tended to spend slightly more time in the colored settings, indicating a higher level of engagement. This suggests that color plays a critical role in creating virtual landscapes that are more emotionally supportive and immersive.

5 Discussion

This study examines how monochrome and colored virtual landscapes (VL) influence emotional and physiological responses across natural, artificial, and interior environments. Natural VLs promote relaxation and comfort, while monochrome urban settings emphasize structure and focus, offering the potential for stress management and productivity enhancement. Interior environments highlight the importance of ergonomic design and lighting in fostering comfort and efficiency. These findings have applications in digital therapy, urban planning, and architectural design, offering insights for crafting restorative and human-centered spaces. Future research with diverse samples could further explore how VLs shape emotional experiences, guiding innovative approaches in both physical and digital design practices.

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