Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences

Tome 77, No 10, 2024

ENGINEERING SCIENCES

Automatics and informatics

INTEGRATING VIRTUAL REALITY AND COLOUR PSYCHOLOGY IN THE DESIGN OF SMALL LIVEABLE SPACES

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Received on July 5, 2024
Presented by Ch. Roumenin, Member of BAS, on September 17, 2024

Abstract

Virtual reality (VR) technology has quickly advanced, providing new ways for immersive and interactive experiences. This research aims to integrate colour theories into the practical application of Vanspace 3D software. The study investigates the perceptual dimensions of colour schemes, lighting, and their collective impact on spatial perception within confined living spaces. Through a step-by-step equipping and furnishing process, the software's versatility is demonstrated, accommodating various design elements, from solar panels to custom furniture. Monochromatic and analogous schemes align with nature-inspired living, while triadic schemes emphasise balance. Complementary and tetradic schemes showcase harmonious and rich designs, and warm and cold colour schemes present contrasting atmospheres, highlighting design adaptability. Exploration of contrast, saturation, and lighting underscores their influence on aesthetics and functionality. Findings suggest that colour choices significantly impact perceived size and ambience, offering recommendations for creating spacious illusions in confined spaces.

Key words: virtual reality, colour psychology, Vanspace 3D, camper van

Introduction. Recent advances in virtual reality (VR) technology have changed how we interact with and see digital spaces. Additionally, VR technology has made great strides, playing a bigger role in design and visualisation. The term "virtual reality" was introduced by Jaron Lanier in 1987. Virtual reality can be

https://doi.org/10.7546/CRABS.2024.10.11

determined as a virtual object within a virtual environment [1]. More specifically, it refers to a computer-generated simulation or artificial recreation of real-life environments or situations. VR immerses users, making them feel as if they are directly experiencing the simulated reality, primarily by engaging their vision and hearing [2]. VR applications immerse users in computer-generated environments that mimic reality using interactive devices. A key application of VR technology has consistently been training for real-world activities. Virtual reality is transforming not only the structural design of homes but also their interior design. Using immersive 3D visualisations, VR technology can simulate various aspects of interior spaces, including lighting, ventilation, colour schemes, and furniture. These platforms enable designers and homeowners to visualise the aesthetics and functionality of a property.

A camper van is a vehicle outfitted with sleeping accommodations and cooking facilities, enabling individuals to reside, prepare meals, and rest within it. VR tools, such as the Vanspace 3D software, enable the creation of intricate 3D models of custom camper vans, providing a virtual environment where designers, architects, and even individuals without professional experience in 3D design can visualise and experiment with different design elements. Vanspace 3D software is designed to be highly intuitive, allowing users to begin designing custom camper vans without prior experience. The objective is to provide accessible tools for creating personalised recreational vehicle (RV) plans, eliminating the need for extensive training or practice. The software features a user-friendly interface that grants access to robust tools.

The colour perception depends on the acuity of vision, and this acuity varies among individuals. The colour perception process is intricate and influenced by numerous factors, encompassing physiological, mental, and circumstantial elements [3]. Agoston [4] introduced the idea of 'psychological colour', contending that the characteristics of colour evoke psychological responses. Colour perception is distinctive and intriguing as it arises from our neural structure and visual physiology, rather than being quantifiable in the physical realm. Colour psychology investigates how each colour influences an individual's mood, cognitive abilities, creativity, and productivity. This theory is grounded in scientific research on the effects of various hues across the spectrum on the human brain. It stands out as a potent tool in interior design, capable of profoundly affecting the atmosphere of a room more than any other factor. Additionally, each colour in interior design is linked to specific psychological effects. For instance, being surrounded by calming colours like blue or green induces a sense of relaxation, while vibrant tones like red, maroon, or orange evoke feelings of energy and passion. Similarly, neutral colours such as white or grey elicit a sense of serenity. Nevertheless, individuals may react differently to the same shade. What is more, the perception of colour can be altered by variables such as lighting and texture, which carry significant implications for interior design [5].

This paper explores the application of VR technology in the field of interior design, with a specific focus on colour psychology in the design of camper vans. The unique challenge of optimising living spaces within the confined quarters of a camper van demands creative and innovative solutions. Central to this exploration is the pivotal role of colour psychology in shaping the overall design, with an emphasis on creating functional, comfortable, and visually appealing living areas. Despite the rapid evolution of VR technology, the role of colour psychology in interior design, particularly within the unique context of camper vans, remains an underexplored aspect. This study aims to bridge this gap by investigating how colour choices influence the perception of space and aesthetics within the limited confines of a camper van.

Theoretical background. Ćurčić et al. [6] established that colours impact mood, productivity, and psychological well-being in interiors. Their results show that hospitals benefit from calming colours for patient recovery and stress relief. Cugelman et al. [7] presented the usage of the UI Colour Psychology Map in the process of designing or upgrading colour systems, especially when you are under pressure to balance many competing demands across your brand, existing design standards, accessibility requirements, emotional goals, and behavioural design objectives. Dantas et al. [8] made a systematic review of colour psychology research methodologies and limitations and explored research trends in colour psychology from 2006 to 2020. Their finding revealed that colour psychology influences product development and consumer behaviour. Singh et al. [9] have reviewed 50 publications on cognitive design, colours, and visual psychology. The authors established that colours can enhance environments for mental health and visual comfort and children benefit from colourful environments to reduce anxiety and stress.

Previous research [10,11] has underscored the potential of VR to revolutionise traditional design methods, offering designers the ability to meet customer needs more effectively. Phommaly and Yu [12] demonstrate that virtual reality technology can enhance the technical aspects of the home design industry, offering fresh momentum for the growth and prosperity of the entire sector. The findings show that the incorporation of real 3D models and the Virtual Reality Modelling Language (VRML) facilitates the rapid development of furniture designs within a web-based 3D virtual reality display system. Xu et al. [13] designed a VR experiment and a questionnaire to explore how the colour scheme of hotel interior design can influence the emotional experience of hotel guests. The results show that hotel rooms decorated in yellow have a pleasurable effect, and rooms decorated in grey have a calming effect. Stahre [14] emphasised the importance of inter-reflections, the perceived colour of light, colour variations, and shadowing in determining the visual appearance of real rooms. The study identifies challenges in simulating visually realistic spatial colour and light in VR. Abas et al. [15] presented the main advantage of applying AR during the planning stages considering

helping manufacturing designers avoid potential errors typically encountered in this stage.

Methodology. This study focuses on the systematisation of colour theories and their aesthetic analysis. Additionally, this research aims to integrate colour theories into the practical application of Vanspace 3D software. Through this integration, the purpose of this study is to contribute not only to the theoretical understanding of colour psychology in interior design but also to the practical realm of designing functional and aesthetically pleasing camper van interiors. The comparative analysis is applied to examine various colour combinations and layouts in the interior design of a camper van using Vanspace 3D Software. The qualitative approach is used to examine the colour appearance of the camper van.

Vanspace 3D software was utilised for analytical purposes in this study [16]. This software enables users to design and construct customised recreational vehicles (RVs). After selecting the vehicle type, users can populate the virtual space with various components. The software offers over 400 3D models, including furniture, storage cabinets, appliances, and other items, most of which are based on actual products. Users can switch to a first-person, 3D mode at any stage of the design process, allowing them to navigate a virtual representation of their camper. This feature enables users to view their creations from multiple angles and make necessary adjustments to the layout. Once satisfied with the floorplan, the design can be exported as an external file to serve as a blueprint for constructing the actual camper.

The virtual designs were guided by established models, theories, and principles of colour psychology. Drawing from established colour theories basics such as a colour wheel, colour schemes, colour temperatures, colour combinations, colour context, psychology of colour, contrast and saturation, the study aimed to capture the subjective experience of colour combinations within the virtual Camper Van designs. Figure 1 presents various colour theories. The Colour Wheel is a valuable tool in interior design (Fig. 1a). It shows relationships between colours. This tool groups colours into primary, secondary, and tertiary categories. The primary colours are red, blue, and yellow. These colours form the foundation of colours. They cannot be made by mixing other colours. Combining primary colours creates secondary colours like green, orange, and purple. Adding more of one primary colour to a secondary colour creates tertiary colours (ratio 2:1). The formation of coherent colour combinations using the colour wheel is referred to as a colour scheme. Such a scheme provides the appropriate aesthetics in terms of both colour style and visual appeal. Examples of colour schemes are as follows (Fig. 1b):

1. Monochromatic. A monochromatic scheme incorporates a single colour in various tones.
2. Analogous. These colours have a place next to each other on the colour wheel. Analogous colours are inherently pleasing to the eye and such schemes

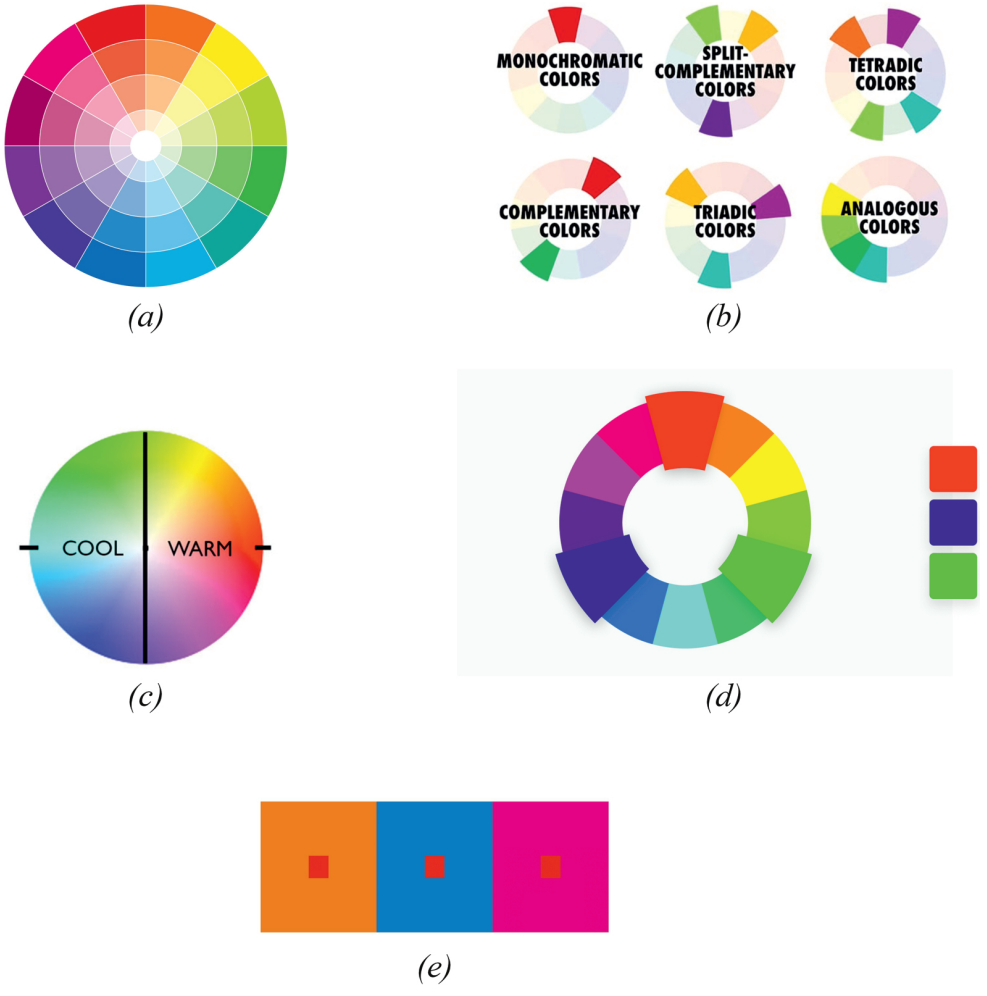


Fig. 1. Colour theories. Source: (a) `https://s.shopeee.com/H15U`, (b) `https://s.shopeee.com/u8hj`, (c) `https://s.shopeee.com/RFM7`, (d) `https://s.shopeee.com/iOmv`, (e) `https://s.shopeee.com/vSmh`. (a) Colour Wheel, (b) Colour Schemes, (c) Colour Temperatures, (d) Colour Combinations, (e) Colour Context

are frequently observed in the natural environment. They offer a more harmonious and less contrasting look.

3. Triadic. This triadic can be created from hues that are spaced out equally on the colour wheel. All primary colours paired together are triadic, and so are all secondary colours.
4. Complementary. These colours stay on opposite sides of the wheel. They create high contrast.
5. Tetradic. This colour scheme is created by selecting four distinct hues from the colour wheel: two sets of complementary colours. A tetradic colour scheme is used to achieve maximum contrast and balance.

6. Split Complementary. A Split Complementary colour scheme is generated by choosing a base hue, and then combining the two hues on either side of its complementary colour.

Warm hues are present around a particular colour in a colour wheel (Fig. 1c). Warm-toned colours (reds, oranges, yellows, and pinks) can create a warm, welcoming, and cosy atmosphere within a space. Cool-toned colours (grey, blue, silver, and most whites) can impart a sense of stability, tranquillity, and cleanliness to a room. Combining any three primary spectral colours – red, green, or blue – with another colour, and incorporating white, results in a colour combination (Fig. 1d). The process of forming these combinations revolves around the use of the colour wheel, beginning with primary colours and progressing to secondary and tertiary colours. According to colour context, colour has different meanings in various settings (Fig. 1e). Consequently, colours can elicit various emotions and interpretations, with their effectiveness hinging entirely on the context. This context encompasses both the physical space and the psychological perspective, playing a crucial role in establishing the ideal atmosphere. Contrast and saturation can be used to enhance visual interest and readability. Saturation plays a key role in interior design and refers to the intensity or purity of a colour. High saturation means vivid colours and low saturation offers softer tones. Highly saturated colours energise a space. On the other hand, low saturation colours create a calm and warm atmosphere. The contrast in interior design refers to colour combinations of darker and lighter shades. Contrast in colours has to create visual interest [17].

Results and discussion. This study builds upon previous research that explored the application of virtual reality (VR) technology in the interior design of a camper van, specifically focusing on the role of colour perception [18]. In the earlier study, VR technology was employed to create 3D models of rooms and spaces, allowing for more accurate and detailed designs. It was suggested that non-professionals in 3D design could effectively use Vanspace 3D software to design functional and comfortable living spaces. Vanspace 3D Software allows for the creation of custom furniture that aligns with user preferences and dimensions. It features an extensive library for designing various systems, including electrical (solar panels, controller, battery), water installation, wet rooms (bathrooms with toilets), gas systems, and additional seating.

Building on these findings, the current study extends the investigation by focusing specifically on the colour aspects of living spaces within a camper van. After equipping and furnishing the camper van using Vanspace 3D Software [18], we conducted a thorough colour analysis. The colour analysis involved systematic probing of various colour schemes, temperatures, combinations, context, contrast, saturation, and psychological effects. The objective of this study is to analyse the effect of colour on interior design by creating a professional-looking 3D layout of a camper van using Vanspace 3D Software.

The various colour schemes are probed in Vanspace 3D Software (Fig. 2). The Colour Wheel is an invaluable tool in selecting harmonious colour combinations for the camper van interior (Fig 2a). In the camper van design, two monochromatic schemes were experimented with, specifically shades of blue and green. (Fig. 2b, c). Monochromatic designs were successful in creating a cohesive and visually appealing interior. Green is closely associated with nature, tranquillity, and growth. It symbolises harmony and balance, making it a suitable choice for spaces where a connection with the natural environment is desired. On the other hand, blue is linked to serenity, calmness, and reliability. It is often associated with the sky and the sea, evoking feelings of expansiveness and tranquillity. Blue, especially in lighter tones, contributes to an illusion of space, making it suitable for small living areas. Both green and blue monochromatic colour schemes align well with the concept of living and travelling in a camper van, especially when the goal is to be close to nature. These colours evoke natural elements, bringing the outdoors inside and enhancing the connection with the surrounding environment.

Analogous schemes created a pleasing and harmonious visual flow within the camper van interior (Fig. 2d). The combination of analogous blue, green, and yellow colours contributes to an open and welcoming atmosphere in small living spaces. The blend of calming blues, nature-inspired greens, and energetic yellows enhances the overall liveability of the camper van. The analogous colour scheme in these natural tones aligns seamlessly with the concept of nature-inspired living. It brings the freshness of the outdoors inside, fostering a connection with the surrounding environment. In the implementation of the triadic colour scheme, incorporating red, green, and blue into the camper van interior yielded interesting and contrasting outcomes (Fig. 2e). According to colour psychology, red is often associated with power, anger, and danger. It can evoke strong emotions and intense reactions. Green and blue played a vital role in balancing the emotional impact of red. These colours, associated with calmness and nature, contributed to a more balanced and serene atmosphere within the camper van. Given the limited living space in a camper van, the potential psychological effects of red, such as heightened emotions and energy, must be weighed against the need for a harmonious and comfortable living environment.

To probe complementary colour schemes, high-contrast combinations such as orange and blue were used (Fig. 2f). The combination of orange and blue in the camper van interior design resulted in a harmonious and balanced visual composition, leveraging the psychological associations of these colours. Orange is commonly associated with warmth, happiness, and energy. It brings a sense of enthusiasm and vibrancy to the living space. Blue is linked to serenity, calmness, and reliability. It has a soothing effect and promotes a sense of stability. In conclusion, the warm tones of orange were complemented by the cool, calming tones of blue, resulting in a dynamic yet comforting environment. The applied tetradic colour scheme incorporates four distinct hues – yellow, orange, blue, and purple

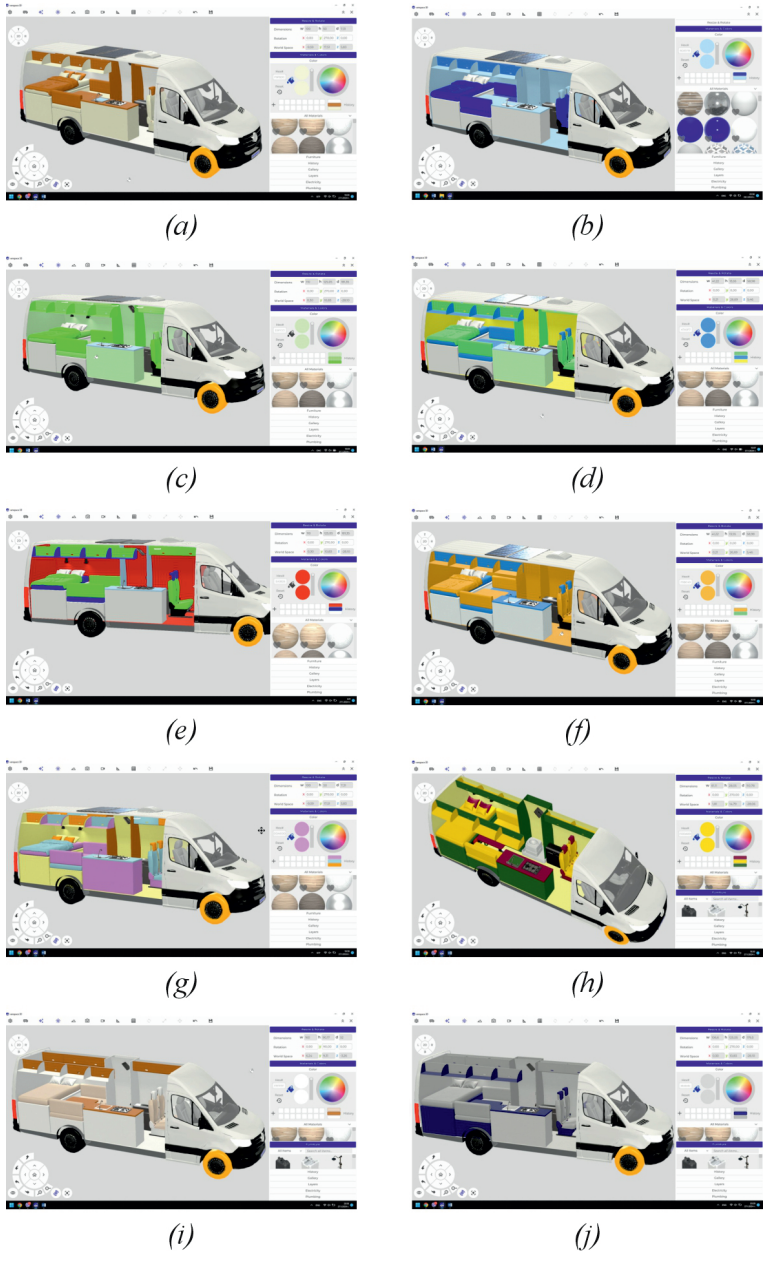


Fig. 2. Probing different colour schemes in Vanspace 3D Software. Source: Author's presentation. (a) Colour Wheel in Vanspace 3D Software, (b) Monochromatic colour schemes in blue, (c) Monochromatic colour schemes in green, (d) Analogous colour schemes, (e) Triadic colour schemes, (f) Complementary colour schemes, (g) Tetradic colour schemes, (h) Split Complementary colour schemes, (i) Warm colour schemes, (j) Cold colour schemes

(Fig. 2g). Using multiple colours in a small space requires careful consideration. While the tetradic scheme introduces richness, it may be challenging to balance without overwhelming the limited area. It requires thoughtful placement, perhaps focusing on specific elements or areas to avoid overwhelming the space. Split complementary colour schemes in yellow, green, and red-purple have been probed (Fig. 2h). This combination aims to create contrast while maintaining visual harmony. The split complementary scheme offers versatility and balance, making it suitable for small living spaces like camper vans. Yellow brings energy and vibrancy, green contributes a calming effect, and red-purple adds depth and richness. The overall impact is dynamic, engaging, and visually appealing. Warm colour schemes in beige and brown involve using a range of hues within the warm colour spectrum (Fig. 2i). This creates a cohesive and comforting atmosphere. Warm colour schemes with beige and brown can be suitable for small living spaces like camper vans. The earthy tones create a cosy and inviting environment without overwhelming the limited space. In the context of small liveable spaces, the integration of advanced technologies such as virtual reality can mitigate certain risks, much like how volatility visualisation tools are used for financial and tourism risk management [19]. On the other hand, cold colour schemes in dark blue and grey involve using cool tones to create a serene and modern aesthetics (Fig. 2j). The combination aims to evoke a sense of calmness and sophistication. The combination of dark blue and grey contributes to a modern and stylish interior. The cool tones add a touch of sophistication and elegance to the small space.

Various lighting, contrast, and colour saturation levels have been probed to assess their impact on the overall aesthetic and visual appeal of the camper van interior. The comparison involves two designs – one with enhanced colour saturation and contrast (Fig. 3a), and another without (Fig. 3b). The design with increased colour saturation exhibits more vivid and intense shades of blue and grey. This heightened saturation adds energy and visual interest to the interior (Fig. 3a). The saturated design may evoke a more energetic and lively mood, while the unsaturated design contributes to a calmer and more subdued atmosphere. The unsaturated design is supposed to be more suitable for small living spaces like camper vans (Fig. 3b).

Different lighting setups in camper van interior designs have been probed to evaluate how they influence the perception of colour, ambience, and functionality within the confined space (Fig. 3c, d). A scenario with fewer lights creates a more subdued and intimate ambience. It enhances the warmth of the colour scheme, providing a cosy atmosphere suitable for relaxing evenings. Increasing the number of lights results in a brighter and well-illuminated interior. This configuration is ideal for tasks that require ample lighting and contributes to an open and airy feel. When utilising warm colour schemes with different shades of brown, proper lighting is crucial. Adequate lighting prevents the space from feeling too dark and ensures that the richness of brown tones is highlighted (Fig. 3c). Whereas, good

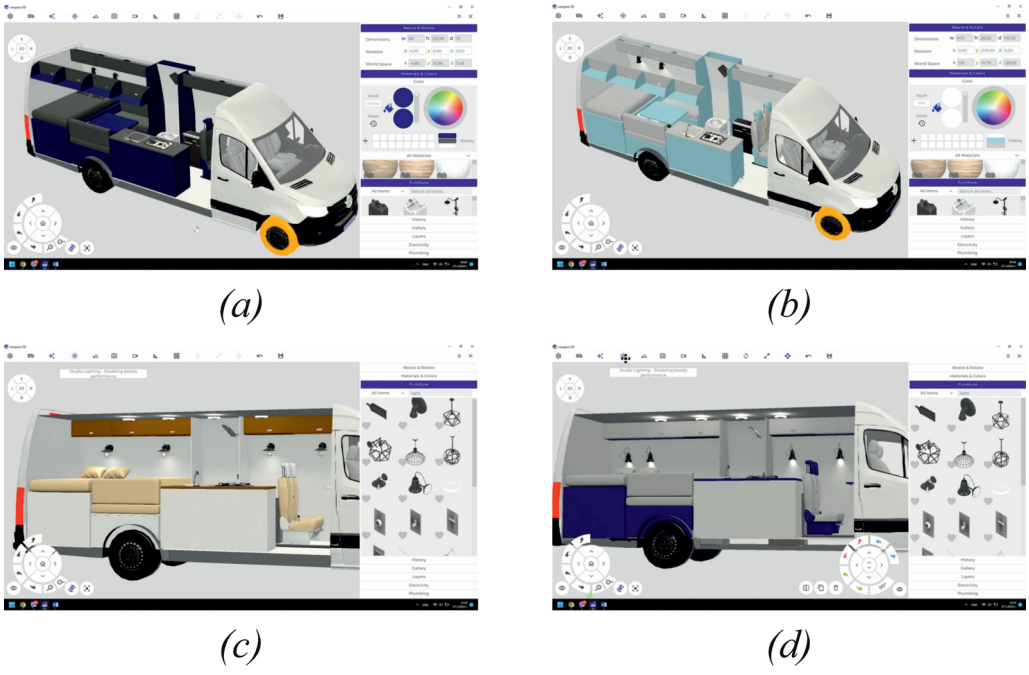


Fig. 3. Probing colour saturation and lightening in Vanspace 3D Software. Source: Author's presentation, (a) Saturation, (b) Hue, (c) More lights and warm colours, (d) More lights and saturated colours

lighting is essential for highlighting the effects of colour saturation and contrast (Fig. 3d). Well-designed lighting can enhance the vibrancy of saturated colours or provide a gentle glow to muted tones.

Conclusion. Virtual reality technology is revolutionising the interior design of small living spaces, such as camper vans. This study demonstrates how Vanspace 3D software can integrate colour psychology and aesthetics analysis to create visually appealing and psychologically comfortable environments. Additionally, Vanspace 3D is highly user-friendly, making it accessible to individuals without prior experience or knowledge of 3D modelling software.

By exploring various colour schemes and lighting setups, it was found that colour choices significantly impact perceived size and ambience. These insights provide valuable guidelines for designers aiming to maximise the liveability of small spaces. The systematic probing of various colour schemes showcased the software's capacity to explore design possibilities. Monochromatic schemes in blue and green demonstrated cohesion and a connection with nature. Analogous colour combinations fostered a visual flow, aligning well with the concept of nature-inspired living. Triadic schemes, while introducing contrasting elements like red, highlighted the need for balance in confined spaces. Complementary colour schemes, such as the pairing of orange and blue, illustrated a harmonious balance between

warm and cool tones. The tetradic scheme, with yellow, orange, blue, and purple, showcased richness but emphasised the challenge of balancing multiple colours within a small space. Split complementary schemes, carefully combining yellow, green, and red-purple, demonstrated versatility and visual appeal. Exploring warm colour schemes in beige and brown evoked a cosy and inviting atmosphere, suitable for small living spaces. Conversely, cold colour schemes in dark blue and grey presented a modern and sophisticated aesthetic, adding a touch of elegance to the confined space. The study's findings align with the consensus that colour choices significantly impact the perceived size and ambience of interior spaces. Recommendations for camper van interiors include blending warm earth tones with whites and beiges to create an illusion of spaciousness [20]. Future research could investigate the long-term psychological effects of various colour schemes and further enhance the application of VR in interior design. Additionally, it will include a comprehensive pilot study with a factorial experimental design and statistical analysis to quantitatively assess the impact of colour choices on perceived space and ambience.

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