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Interior Wall Color and Emotional Responses: Evidence from Group Therapy Rooms

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Abstract

Color, as an environmental stimulus, shapes emotional experience in architectural spaces and is critical in group therapy rooms, where spatial conditions must support psychological safety, cohesion, and emotion regulation. This study examined the effect of interior wall color, systematically varied as the sole manipulated variable, in an immersive virtual reality (VR) simulation of a group therapy room. In a within-subjects design, 57 participants experienced 17 wall-color conditions of the same virtual room. Emotional responses were measured with the Self-Assessment Manikin (SAM) and interpreted within the PAD (Pleasure–Arousal–Dominance) framework, focusing on valence and arousal. Given the within-subjects design and the ordinal nature of SAM ratings, data were analyzed using nonparametric statistical methods, including the Friedman test, which is robust to violations of normality in repeated-measures comparisons, and Spearman correlations, alongside cluster analysis. Wall color significantly influenced valence: in post hoc comparisons with Holm-adjusted p values, dark green and turquoise green yielded higher valence ratings than dark red and light red, whereas effects on arousal were weaker. Although several other hues showed relatively higher pleasantness descriptively, the strongest inferential contrasts emerged for dark green and turquoise green. At the color-category level, cool colors elicited higher valence than warm and neutral colors. Cluster analysis yielded seven emotional profiles, providing a finer-grained description than the warm–neutral–cool classification. Correlation analyses indicated that hues (dark cream, turquoise green, light blue, light cream, and dark green) produced coherent valence–arousal profiles, whereas others were associated with heterogeneous responses. These findings suggest that interior wall color can structure the emotional experience of group therapy rooms and that color choices guided by PAD-based response patterns may support evidence-based design of therapeutic spaces, moving beyond aesthetic intuition.

Keywords

Interior Wall Color, Emotional Responses, Virtual Reality (VR), Group Therapy Rooms, Therapeutic Interiors.

Introduction

Color, as a fundamental environmental stimulus, plays a pivotal role in shaping emotional, perceptual, and cognitive experiences in architectural spaces (Elliot & Maier, 2014; Elliot, 2015; Valdez & Mehrabian, 1994). In therapeutic environments, where psychological safety and emotion regulation are central, color functions as an emotional modulator, influencing attentional focus, emotional states, and social interaction (Cha et al., 2020; Elliot, 2015; Sinclair, 2021). Research examines how color shapes emotional responses in healthcare, counseling, educational, and residential treatment settings (Cha et al., 2020; Weijs et al., 2023).

Group-therapy rooms present distinct psychological and spatial demands. They must support individual reflection, collective engagement, trust, acceptance, and emotional expression (Gryesten et al., 2024; Hearn et al., 2025; Yalom & Leszcz, 2020). Architectural features, including color, lighting, and spatial enclosure, shape perception and interaction (Kleinberg, 2011; Ulrich et al., 2008; Yalom & Leszcz, 2020). Among these attributes, color can influence emotion and group cohesiveness (Sinclair, 2021). Nevertheless, most empirical investigations have focused on variables such as privacy, spatial configuration, and seating arrangement (Kleinberg, 2011; Yalom & Leszcz, 2020), leaving the independent effect of color rarely examined systematically.

To address this gap, the present study isolates interior wall color, defined by hue, lightness, and chroma, as the sole independent variable in an immersive virtual reality (VR) simulation of a group-therapy room, while holding surface material and texture constant. A total of 57 participants were exposed to 17 wall-color conditions, each based on empirical observations from group-therapy sessions. Participants' emotional responses were measured using the Self-Assessment Manikin (SAM) and interpreted through the PAD (Pleasure–Arousal–Dominance) framework, with emphasis on valence (pleasant–unpleasant) and arousal (the level of emotional activation) (Bradley & Lang, 1994; Cha et al., 2020; Mehrabian & Russell, 1974). By integrating immersive simulation, the PAD framework, SAM, and nonparametric analyses suited to within-subjects' ordinal data, this study addresses environmental psychology and therapeutic architectural design. Focusing exclusively on color as a controllable stimulus allows analysis of emotional responses to chromatic variations in group-therapy rooms. The primary objectives of the study are to:

- Examine emotional responses to a systematic range of interior wall colors in a simulated group-therapy room.
- Identify emotional patterns in color-induced valence–arousal structures.
- Offer empirically grounded insights to guide color strategies for group-therapy rooms, independent of material and textural properties.

Literature Review

1. *The PAD Model and Emotion Assessment*

The PAD framework is widely used to analyze emotional responses to environments, with work focusing on valence and arousal. Foundational studies identify these two dimensions as central for environmental emotional states (Mehrabian & Russell, 1974; Russell & Mehrabian, 1977). The Self-Assessment Manikin (SAM) is a nonverbal measure of valence and arousal (Bradley & Lang, 1994). In architecture and environmental psychology, variation of color parameters in real or virtual settings has been linked to patterns in self-reported emotional responses and in physiological indices such as heart rate (HR), heart rate variability (HRV), and electrodermal activity (EDA). These converging findings highlight the value of distinguishing valence and arousal for design-oriented applications (Valdez & Mehrabian, 1994; Weijs et al., 2023). Convergence between these self-report measures and cortical markers (e.g., steady-state visually evoked potentials (ssVEP) and autonomic nervous system (ANS) indices has been documented, and neuroimaging studies identify cortical and subcortical pathways involved in emotion regulation that frame this cross-modal convergence (Lang et al., 1993; Keil et al., 2005; Wager et al., 2008)

2. *Color and Emotional Modulation in Interior Spaces*

Accumulating evidence indicates that a warm–cool dichotomy is insufficient for predicting emotional responses to color; both the direction and magnitude of effects on valence and arousal depend on the combined configuration of hue, lightness (brightness), and chroma (Elliot & Maier, 2014; Elliot, 2015; Valdez & Mehrabian, 1994). Across picture-viewing and immersive virtual reality paradigms, this multidimensional pattern emerges in self-report, physiological, and cortical measures, with the degree of convergence among indices varying as a function of environmental design and the strength of the color manipulation (Lang et al., 1993; Keil et al., 2005; Weijs et al., 2023). In immersive architectural environments, manipulations of lightness and, in some cases, hue alter emotional appraisals and modulate autonomic and electrocortical markers. Comparisons of blue versus achromatic (white) interiors reveal increased variability in skin conductance and respiration, together with changes in frontal theta and gamma activity, and frontoparietal connectivity, whereas effects on heart rate and heart rate variability are smaller and more consistently observed when contrasting colored rooms with baseline periods rather than between hues per se (Bower et al., 2022; Bower et al., 2023; Weijs et al., 2023). Highly saturated reds are typically linked to greater perceived tension and unpleasantness, yet heart rate differences between red and cooler or achromatic schemes (e.g., blue, white, green) remain heterogeneous across studies (Cha et al., 2020). Field research in residential settings similarly indicates that blue interiors are most preferred, perceived as facilitating studying, and associated with calmer mood states (Costa et al., 2018). Overall, these findings suggest that color strategies in therapeutic interior design should be grounded in controlled combinations of hue, lightness, and chroma rather than in broad categorical labels such as "warm" versus "cool" (Elliot & Maier, 2014; Valdez & Mehrabian, 1994; Weijs et al., 2023).

3. *Color in Therapeutic Contexts: Emotional Safety and Interpersonal Dynamics*

Therapeutic environments that support self-disclosure and vulnerability are expected to promote privacy, safety, and social support (Ulrich et al., 2008). Although empirical studies of group-therapy rooms are limited, research in counseling offices, outpatient settings, and psychiatric units shows that chromatic and visual attributes influence emotional appraisals and users' experience of care (Sui et al., 2023). In counseling and mental health spaces, soft blue- and green-toned schemes and low-contrast neutrals are frequently associated with calmness and more positive evaluations, whereas highly saturated reds and strong contrasts are linked to perceived tension and less favorable judgments (Liu et al., 2014; Sui et al., 2023). Parametric manipulation of hue, lightness, and chroma in CIELAB space has produced coherent response surfaces on pleasant–unpleasant, calm–tense, and safe–fearful scales, with a light, desaturated blue yielding the most favorable impressions, including higher perceived safety (Liu et al., 2014). In telepsychology contexts, both clinicians and clients prefer virtual backgrounds with moderate naturalness and visual complexity, often incorporating vegetation and water, which are described as more comfortable and supportive of the therapeutic process than monotonous or highly artificial scenes (Lobato Rincón et al., 2025). Qualitative accounts of in-person therapy emphasize that rooms perceived as safe and not overly clinical enhance engagement (Sinclair, 2021). Across noninpatient mental health facilities, design strategies using non-institutional, homelike color palettes, supportive lighting, and warm textural finishes consistently correspond to calmer atmospheres, a stronger sense of control, and more constructive interpersonal interaction (Bodryzlova et al., 2024; Sui et al., 2023).

4. *Virtual Reality as a Methodological Tool in Color Research*

Virtual reality (VR) allows precise manipulation of color parameters while balancing experimental control, ecological validity, and presence (Cha et al., 2020; Weijs et al., 2023). VR environments effectively induce emotional states and elicit self-reports that reflect real-world experience. Physiological evidence further indicates that emotional response patterns in VR approximate those in physical settings, particularly in self-report and selected physiological indices (Marín-Morales et al., 2018; Marín-Morales et al., 2021). This partial convergence supports immersive VR as a methodological platform for studying emotional responses to environmental design features and justifies its use in the present study.

5. *Research Gap and Rationale for the Study*

A key gap in the group therapy literature is the lack of standardized reporting of wall color characteristics in studies that manipulate interior wall color as an independent variable. This study, therefore, characterizes valence–arousal patterns for a controlled palette of wall colors to provide a systematic basis for chromatic decisions in group-therapy room design.

Methodology

1. *Research Design*

The study employed a within-subjects repeated-measures design in a controlled laboratory setting. Each participant viewed 17 virtual interior conditions identical except for wall color, enabling within-subject comparison of emotional responses. Stimuli were presented via a head-mounted virtual reality (VR) display to ensure consistent perception across conditions. To minimize order effects, wall color sequences were randomized for each participant. An a priori power analysis for the main Friedman test (17 levels), assuming a medium effect size (Kendall's $W = 0.30$), was conducted using Monte Carlo simulation. Results indicated that a sample size of 57 participants yielded statistical power ≥ 0.99 (95% $CI = 0.998–1.000$) at $\alpha = .05$.

2. *Participants*

Participants were recruited from a psychological counseling center in Tehran providing regular group therapy. To enhance ecological validity, the accessible client population was targeted. In total, 73 adults (aged 18–45 years) provided written informed consent, and data confidentiality was maintained. All volunteers completed two screening instruments: the Beck Depression Inventory–II (BDI–II) to assess depressive symptom severity and the Brief Interpersonal Reactivity Index (B-IRI) to evaluate empathy and socioemotional sensitivity. Color vision was assessed using a two-alternative forced-choice (2AFC) task on a calibrated display; only individuals who met a performance threshold were retained. Exclusion criteria were BDI–II scores in the severe range, markedly low B-IRI scores, and clinical non-approval by therapists due to emotional instability or severe psychopathology. The final sample comprised 57 participants (M = 26.4 years, SD = 6.3; 35 women, 22 men), all fluent in the national language and with prior group therapy experience.

3. *Experimental Setting*

- **Spatial Configuration:** The simulated room represented an 8 × 8 m space with a ceiling height of 3 m. A single entrance door was positioned on one wall, and 10 identical neutral-colored chairs were arranged in a symmetric circle to facilitate eye contact and equal participation. The number of seats aligned with clinical guidelines for optimal group size in group therapy (8–12 members) (Yalom & Leszcz, 2020). To isolate the effect of wall color, potentially distracting elements (additional furniture, textures, artwork) were removed. Lighting conditions were held constant to avoid shadows and color distortion. VR stimuli were presented on-site at the same counseling center (Lu & Lau, 2025).
- **Wall-Color Stimuli:** Seventeen interior wall colors were selected based on prior empirical work in environmental psychology and therapeutic spatial design, as well as the research team's architectural experience and design-informed judgment (Bower et al., 2022; Costa et al., 2018; Liu et al., 2014; Ulrich et al., 2020). The set covered warm, cool, and neutral colors, providing perceptual variety and relevance to therapeutic architecture (Figure 1). Color specifications were

defined in two standard spaces: sRGB for digital rendering and CIELAB for perceptual uniformity (full RGB/CIELAB specifications in Endnote 1).

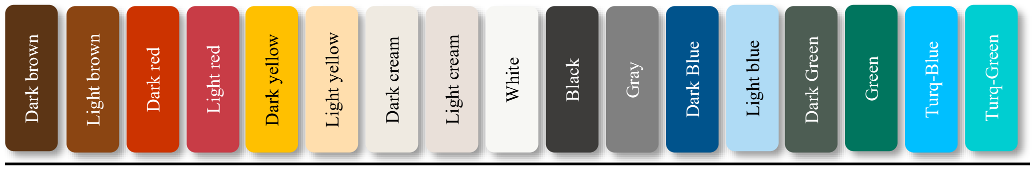

Figure 1: *The 17 selected interior wall colors used in the simulation*

- **Control of Variables:** The independent variable was wall color. The dependent variables were emotional responses along the valence and arousal dimensions. Other environmental, individual, and situational factors were controlled or documented and are summarized in Table 1.

4. *Experimental Procedure*

Each stimulus was displayed for 5 seconds, after which participants completed the Self-Assessment Manikin (SAM) ratings. SAM assessed valence (1 = very unpleasant to 9 = very pleasant) and arousal (1 = low activation to 9 = high activation). As a pictorial, nonverbal instrument, SAM supports rapid evaluation of emotional states. To reduce color afterimages and prevent adaptation, a neutral gray screen was presented for 3 seconds between stimuli (Figure 2).

5. *Data Analysis Strategy*

All statistical analyses were conducted in R (version 4.5). Given the within-subjects design and the ordinal nature of the SAM ratings, a nonparametric analysis strategy was adopted. All inferential tests were conducted using two-tailed criteria with a significance level of $\alpha = .05$.

Table 1: *Overview of Variables and Control Methods.*

Type of Variable	Variable	Level / Range	Control Method
Independent	Wall color	Seventeen colors (warm, cool, neutral)	Uniform application to all wall surfaces; selection informed by psychological evidence
Dependent	Emotional response	Valence (pleasant–unpleasant), arousal (low–high)	Assessment using the SAM scale after each color exposure
Controlled – Environmental Factors	Lighting, spatial arrangement, and viewing angle	Neutral white lighting (4000 K), 350-lux illuminance; constant room geometry and seating layout	Fixed lighting and geometry; constant viewing position within the simulated environment
Controlled – Participant Characteristics	Non-essential elements	Extra furniture, textures, and décor	Removed from the VR scene to minimize perceptual distraction
Controlled – Situational Factors	Psychological status	Depression, empathy, and color vision	Screening using the BDI-II, B-IRI, and a 2AFC color-vision task; exclusion of severe cases

- **Descriptive Statistics:** For each of the 17 wall-color conditions, emotional responses were computed separately for valence and arousal. The median and interquartile range (IQR) were reported as robust measures of central tendency and dispersion, and skewness and kurtosis were calculated to characterize distribution shape.

- **Assumption Checking:** Shapiro–Wilk tests indicated significant deviations from normality in 29 % of valence ratings and 47% of arousal ratings ($p < .05$). Consequently, nonparametric procedures were used for all subsequent inferential analyses, which are robust to violations of normality in repeated-measures data.
- **Friedman Test:** To compare median ranks across the 17 wall-color conditions for valence and arousal, Friedman tests were performed, and effect sizes were expressed as Kendall's W and interpreted according to Tomczak and Tomczak's (2014) thresholds: $W \approx 0.10$ (small), $W \approx 0.30$ (medium), and $W \geq 0.50$ (large).

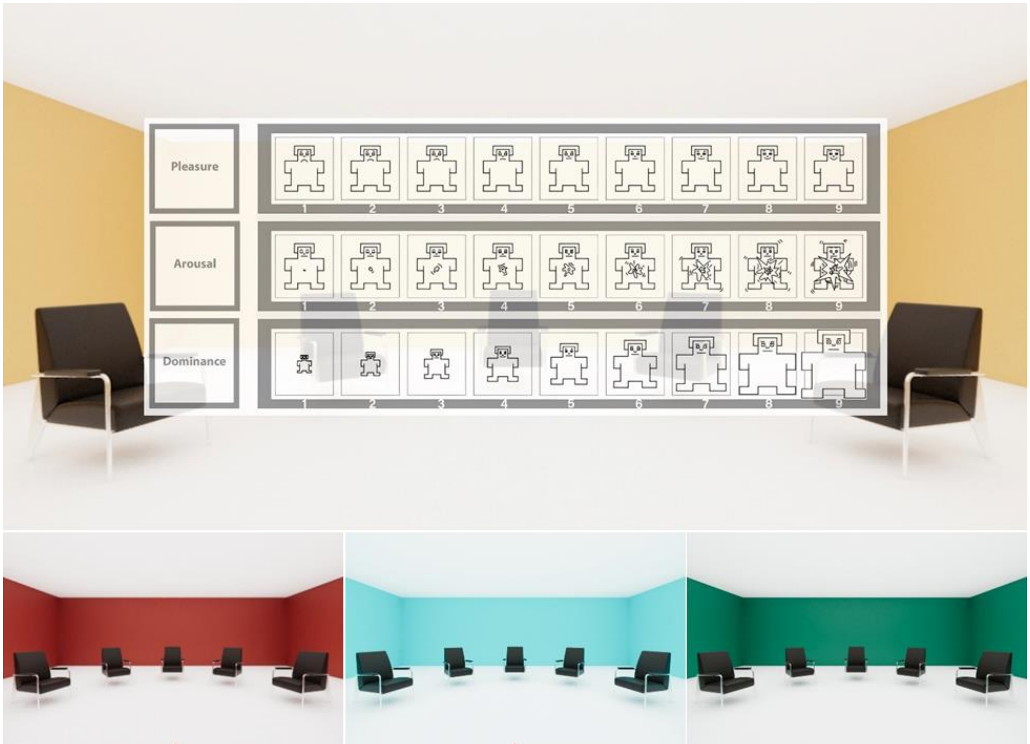

Figure 2: *Representative color stimuli and the in-VR presentation of the SAM scale*

- **Post Hoc Analysis: Wilcoxon Test:** When a Friedman test yielded a significant overall effect, pairwise comparisons among all 17 wall-color conditions (n = 136) were conducted using Wilcoxon signed-rank tests. To control Type I error inflation, the Holm correction was applied to the resulting p-values, and effect sizes (r) were reported and interpreted in line with Cohen's (1988) benchmarks: $|r| \approx 0.10$ (small), $|r| \approx 0.30$ (medium), and $|r| \geq 0.50$ (large).
- **Clustering of Emotional Profiles:** To identify groups of colors associated with similar emotional profiles, partitioning around medoids (PAM) clustering was applied to z-standardized median valence and arousal ratings using Euclidean distance. PAM was chosen over k-means for robustness to outliers and suitability with small cluster-level samples.
- **Valence–Arousal Correlation Analysis:** Given the ordinal nature of SAM ratings and the presence of tied ranks, Spearman's rank-order correlation coefficient (ρ) was used. Analyses were carried out at two levels:
  1. Between-color: median valence and arousal ratings for each of the 17 colors (n = 17) were used to estimate the overall valence–arousal relationship.
  2. Within-color: for each color, separate correlations were computed based on the 57 individual ratings (n = 57).

  Holm correction was applied to p-values in the within-color analyses to control the familywise Type I error rate, whereas no correction was applied at the between-color level due to the single-test design. Effect sizes were reported as ρ and interpreted using common benchmarks: $|\rho| \approx 0.10$ (weak), $|\rho| \approx 0.30$ (moderate), and $|\rho| \approx 0.50$ (strong).

- **Color-Category Level Analysis of Emotional Responses:** To examine the impact of broader color categories, the 17 wall colors were grouped into three categories based on hue similarity: warm, neutral, and cool. For each participant, median valence and arousal ratings were calculated within each band, and within-subject comparisons were performed. Friedman tests assessed overall differences between bands; where significant, Wilcoxon signed-rank tests with Holm correction were used for the three pairwise contrasts. Valence and arousal were analyzed separately, and effect sizes were reported using Kendall's *W* for Friedman tests and r for Wilcoxon tests.

Results

1. *Descriptive statistics*

Valence and arousal statistics for the 17 wall-color conditions are shown in Figures 3 and 4. For valence, dark green and turquoise green had the highest median ratings, followed by light cream, dark blue, light blue, and green in a high pleasantness range. In contrast, dark red, white, and black yielded the lowest median valence ratings (Figure 3). For arousal, black, light blue, turquoise blue, and turquoise green produced the highest median levels, whereas light yellow elicited the lowest arousal. Interquartile ranges (IQRs) were between 1.5 and 2.5, although some colors, notably light yellow, white, black, and light blue, displayed greater dispersion. Skewness and kurtosis (Figures 4) showed valence distributions that were approximately symmetric with slight negative skew and mainly negative (platykurtic) kurtosis. In contrast, arousal distributions were predominantly left-skewed and exhibited mixed kurtosis with a slightly positive mean across colors.

2. *Friedman test results*

To test whether emotional responses differed among the 17 wall-color conditions, two Friedman tests were conducted:

- **Valence:** χ^2 (16) = 113.35, $p < .001$, Kendall's $W = .12$ (small effect size).
- **Arousal:** χ^2 (16) = 58.08, $p < .001$, Kendall's $W = .06$ (small effect size).

3. *Post hoc pairwise comparisons (Wilcoxon tests)*

Within each emotional dimension (valence and arousal), 136 pairwise Wilcoxon signed-rank tests were performed, and adjusted *p*-values were used to control multiple comparisons. For valence, 25 pairwise contrasts remained significant after adjustment. Strongest contrasts were: dark green > dark red ($r = .778$, adjusted $p < .001$), dark green > light red ($r = .742$, adjusted $p < .001$), turquoise green > dark red ($r = .692$, adjusted $p < .001$), and turquoise green > light red ($r = .679$, adjusted $p < .001$). For arousal, five contrasts remained significant after adjustment: black > gray ($r = .603$, adjusted $p = .002$), turquoise green > light cream ($r = .580$, adjusted $p = .016$), light blue > light cream ($r = .536$, adjusted $p = .020$), green > light cream ($r = .557$, adjusted $p = .025$), and dark cream > light cream ($r = .582$, adjusted $p = .026$). All other pairwise comparisons were not significant after adjustment.

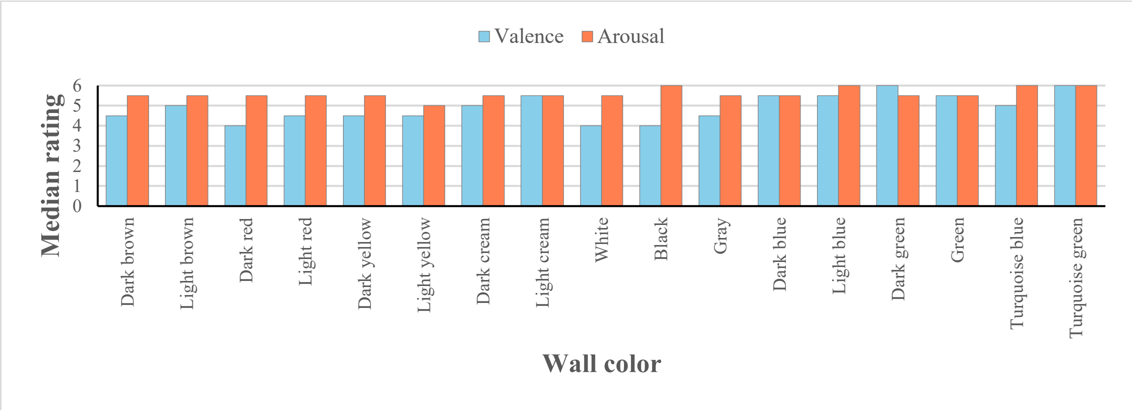

Figure 3: *Median valence and arousal ratings for the different wall-color conditions.*

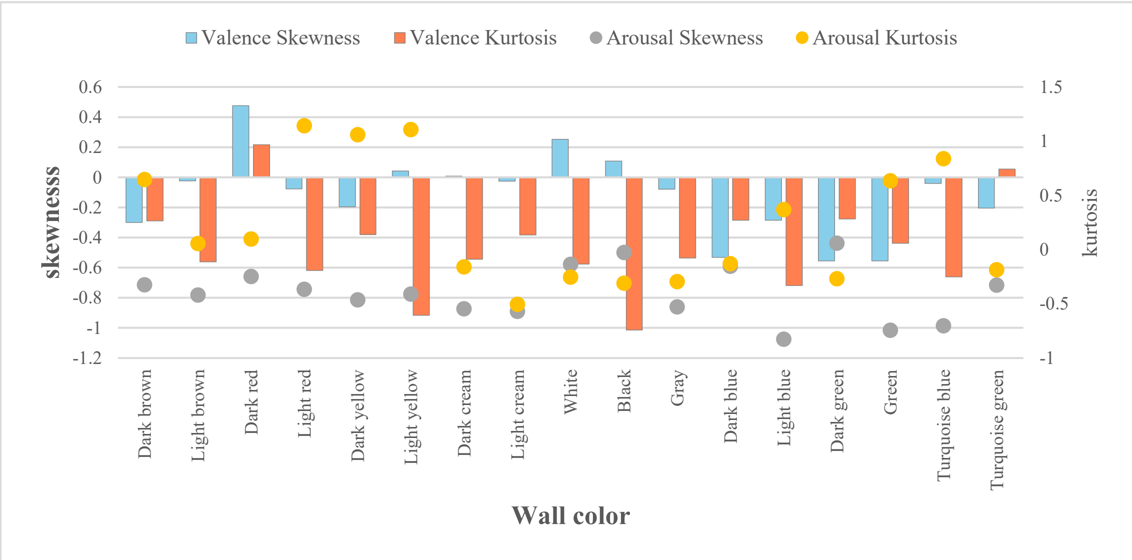

Figure 4: *Comparison of skewness and kurtosis values in valence and arousal ratings.*
Note: Positive skewness means most responses fall at lower values with a few higher scores, whereas negative skewness means most responses fall at higher values with a few lower scores. Positive kurtosis indicates greater central clustering with some farther-out observations, whereas negative kurtosis indicates reduced central clustering and a more evenly spread distribution.

4. *Clustering of emotional profiles*

Partitioning around medoids (PAM) clustering was applied to z-standardized median valence and arousal ratings. Based on the maximum mean silhouette coefficient ($\bar{s} \approx 0.69$), the number of clusters was $k = 7$. Cluster composition, median silhouette, and emotional positions are summarized in Table 2. The clusters were mapped in the two-dimensional valence–arousal space and plotted according to their emotional coordinates in this space (Figure 5). Clusters 1–3 showed high internal coherence ($\bar{s} = 1.00$), grouping colors with similar emotional profiles. Clusters 4 and 6 were single-color clusters ($\bar{s} = 0.00$), reflecting idiosyncratic or potentially outlying response patterns. Cluster 5 showed high cohesion ($\bar{s} = 0.67$), and Cluster 7 moderate cohesion ($\bar{s} = 0.38$), each containing colors with broadly similar, though not fully homogeneous, emotional signatures. Cluster-specific patterns are discussed in the section "Emotional profiles derived from clustering" in the Discussion.

Table 2: *Cluster composition, silhouette values, and emotional positions.*

Cluster	Number of Colors	Colors	Median Silhouette	Emotional Position
1	4	Dark brown, Light red, Dark yellow, Gray	1.00	Neutral-to-negative valence, moderate arousal
2	2	Light brown, Dark cream	1.00	Neutral valence, moderate arousal
3	2	Dark red, White	1.00	Negative valence, moderate arousal
4	1	Light yellow	0.00	Neutral-to-negative valence, low arousal
5	4	Light cream, Dark blue, Dark green, Green	0.67	Positive valence, moderate arousal
6	1	Black	0.00	Negative valence, high arousal
7	3	Light blue, Turquoise blue, Turquoise green	0.38	Positive valence, high arousal

Note: Median silhouette values reflect the internal coherence of each cluster (1.00 indicates complete cohesion; 0.00 indicates no cohesion). Interpretive implications of the clusters are discussed in the Discussion.

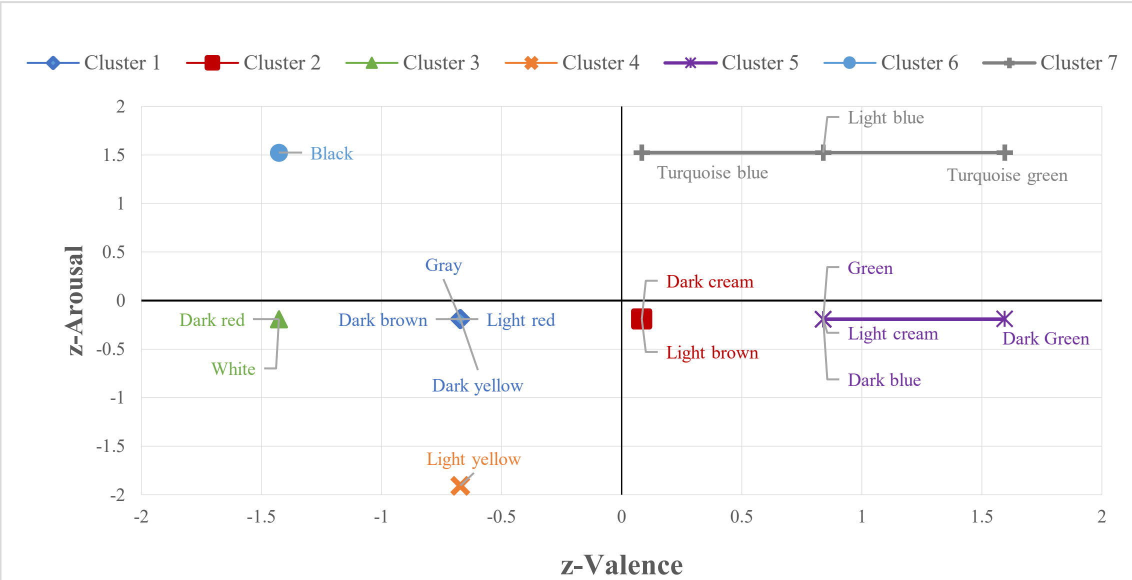

Figure 5: *Scatterplot of clusters in the standardized valence–arousal space.*

5. *Valence–arousal correlation analysis*

At the between-color level, the correlation between median valence and median arousal across the 17 colors was weak and nonsignificant (ρ = .212, p = .413), indicating no consistent relationship between these dimensions. The within-color analyses (Figure 6) showed a differentiated pattern. Positive correlations were observed for dark cream (ρ = .584, adjusted p < .001) and turquoise green (ρ = .574, adjusted p < .001); for light blue (ρ = .488, adjusted p = .017), light cream (ρ = .487, adjusted p = .017), and dark green (ρ = .457, adjusted p = .046); and weaker or negligible values for light brown (ρ = .371, adjusted p = .054), green (ρ = .330, adjusted p = .135), dark red (ρ = .124, adjusted p = 1.000), gray (ρ = .094, adjusted p = 1.000), and dark brown (ρ = .058, adjusted p = 1.000). The strongest negative (nonsignificant) correlation occurred for black (ρ = −.183, adjusted p = 1.000).

6. *Color-category differences in valence and arousal*

The 17 wall colors were grouped into three hue-based categories: warm, neutral, and cool.

Valence. The Friedman test indicated significant valence differences among the three-color categories, $\chi^2(2) = 19.07$, $p < .001$, Kendall's $W = .167$, corresponding to a small-to-medium effect size. Adjusted Wilcoxon tests showed that cool colors produced higher valence than both warm ($r = .57$, adjusted $p = .006$; large effect) and neutral hues ($r = .37$, adjusted $p = .010$; medium effect), whereas the warm–neutral contrast did not reach significance ($r = .188$, adjusted $p = .156$). At the level of individual colors, the warm category was not fully homogeneous: light brown produced higher valence than several other warm hues, and the neutral category was heterogeneous, with light cream at the higher end of the pleasantness range and white and black at the lower end.

Arousal. For arousal, the Friedman test indicated significant color-category differences, $\chi^2(2) = 10.30$, $p = .006$, Kendall's $W = .09$, reflecting a small effect size. Adjusted Wilcoxon comparisons revealed that cool colors elicited higher arousal than both warm ($r = .36$, adjusted $p = .019$; medium effect) and neutral hues ($r = .364$, adjusted $p = .019$; medium effect), whereas warm and neutral categories did not differ ($r = .004$, adjusted $p = .973$). Distributions of valence and arousal for the warm, neutral, and cool bands are illustrated in (Figure 7).

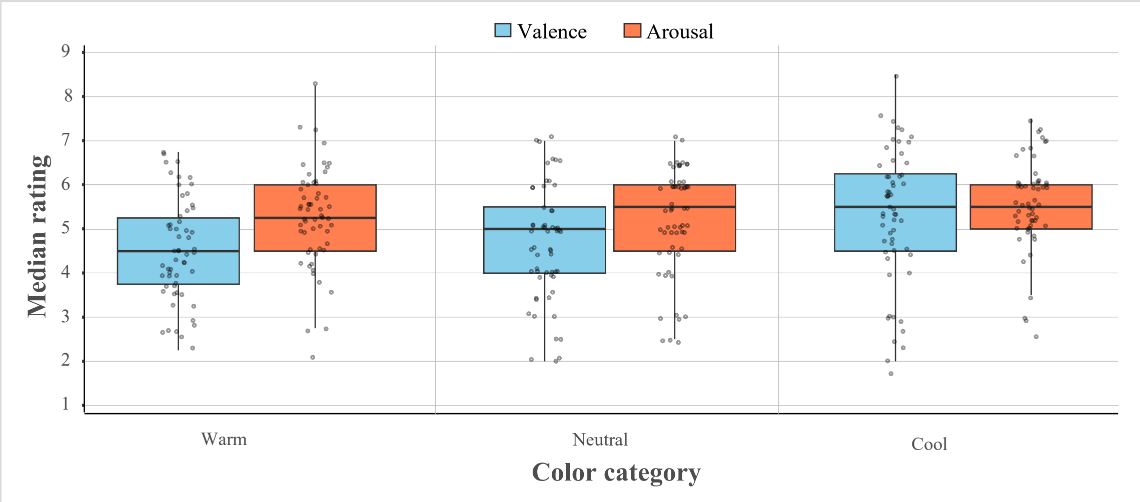

Figure 6: *Distribution of Valence and Arousal Across Color Categories.*

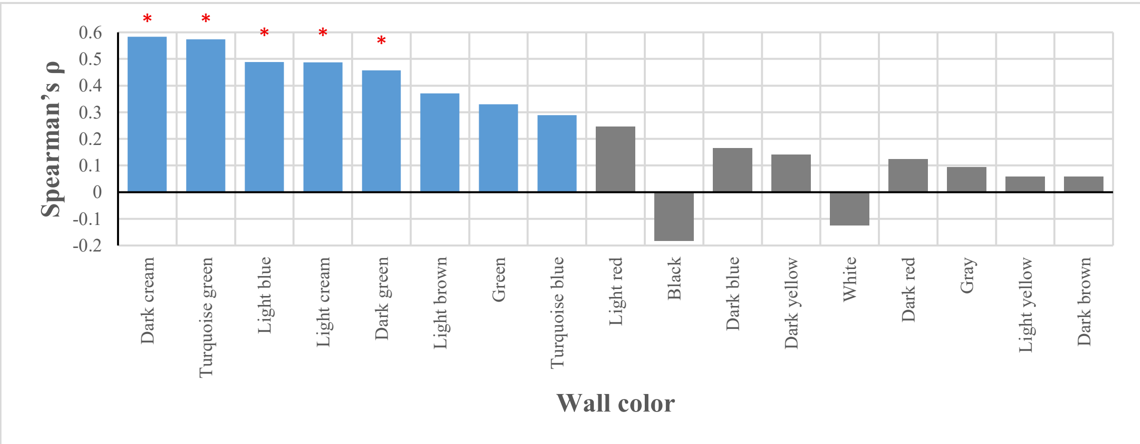

Figure 7: *Within-color valence-arousal correlations for the 17 wall-color conditions*
Note: Asterisks indicate significant correlations after Holm adjustment ($p < .05$).

Discussion

Emotional reactivity to chromatic variation

Friedman tests showed that both valence and arousal differed significantly across the 17 wall colors, although overall effect sizes were small. Stronger differentiation in valence suggests that perceived pleasantness is more directly modulated by wall color than arousal, which is especially relevant in group-therapy settings where emotion regulation is central. Descriptive indices indicated that some colors, particularly white and black, elicited greater variability in responses, pointing to more polarized or ambivalent appraisals, with some participants rating these hues as pleasant and others as unpleasant. This pattern underscores the role of individual differences in chromatic sensitivity and the need to consider interindividual variability when selecting wall colors for group-therapy spaces. Beyond the clear advantage of dark green and turquoise green, the descriptive pattern showed that light cream, dark blue, light blue, and green also occupied a relatively higher pleasantness range, a pattern indicating that the valence dimension exhibits greater responsiveness to chromatic variation.

Chromatic salience in pairwise comparisons

In the Wilcoxon post hoc analyses, dark green and turquoise green were consistently rated as more pleasant than dark red and light red. These contrasts remained robust after adjustment and indicate a clear emotional advantage for certain hues in enhancing pleasantness. By contrast, although five pairwise comparisons in the arousal dimension retained significance after adjustment, the broader pattern suggests that color-related effects on arousal were smaller and less pronounced in the absence of additional multisensory cues such as lighting dynamics or sound. This asymmetry supports the view that valence is more immediately encoded in surface color, whereas arousal may be more sensitive to richer or more complex environmental configurations. Thus, wall color alone appears sufficient to shift pleasantness, while stronger or multimodal stimulation may be required to meaningfully modulate arousal.

Emotional profiles derived from clustering

To probe the structure of emotional responses, the seven-cluster PAM solution served as the basis for interpretation. Clusters 1–3 showed high internal cohesion and grouped colors that elicited similar emotional patterns; they mostly occupied mid-level arousal ranges with very low to near-neutral valence. In contrast, the single-color clusters, Cluster 4 (light yellow) and Cluster 6 (black), captured stimuli with less coherent emotional profiles. Silhouette values support their distinctiveness in valence–arousal space, but their interpretation remains exploratory. Cluster 4 was located in neutral-to-negative valence and low arousal, whereas Cluster 6 occupied low valence and high arousal. Cluster 5 fell within high valence and moderate arousal, and Cluster 7 fell within high valence and high arousal. Overall, these distinctions indicate that emotional responses to color do not follow a simple linear gradient, but instead form discrete profiles in valence–arousal space, with the remaining clusters largely capturing intermediate configurations between these poles. From an applied perspective, clusters characterized by high valence and moderate arousal can, within the PAD framework, be interpreted as reflecting colors with calming, tension-reducing potential, whereas clusters marked by high arousal and low valence correspond to more activating and tension-inducing chromatic conditions. This mapping is pertinent for therapeutic architecture because it allows designers to link emotional profiles directly to environmental choices when configuring wall colors for group-therapy rooms.

Valence–arousal correlations at the color level

At the between-color level, the association between median valence and median arousal across the 17 hues was weak and nonsignificant ($\rho = .212$, $p = .413$), indicating no consistent monotonic relationship when the colors are treated as a single set. Within-color analyses, after adjustment, revealed a more differentiated pattern: only five colors, dark cream ($\rho = .584$, adjusted $p < .001$), turquoise green ($\rho = .574$, adjusted $p < .001$), light blue ($\rho = .488$, adjusted $p = .017$), light cream ($\rho = .487$, adjusted $p = .017$), and dark green ($\rho = .457$, adjusted $p = .046$), showed significant positive correlations. These cases indicate coherent emotional profiles in which increases in pleasantness were systematically accompanied by increases in arousal, a property that may be advantageous in group-therapy contexts seeking both psychological safety and engaged participation. In contrast, black showed a negative, though nonsignificant, correlation ($\rho = -.183$, adjusted $p = 1.000$), suggestive of fragmented or inconsistent emotional responses. Other hues, including light brown ($\rho = .371$, adjusted $p = .054$), green ($\rho = .330$, adjusted $p = .135$), dark red ($\rho = .124$, adjusted $p = 1.000$), gray ($\rho = .094$, adjusted $p = 1.000$), and dark brown ($\rho = .058$, adjusted $p = 1.000$), showed weak or negligible associations between valence and arousal. These findings imply that valence–arousal coupling is not uniform across the color spectrum: some hues give rise to emotionally coherent patterns in which pleasantness and activation rise together, whereas others produce more decoupled or variable responses. From a design standpoint, this suggests that therapeutic color decisions should prioritize hues whose internal emotional structure is more coherent and predictable, particularly when the aim is to support both comfort and active involvement in group processes.

Emotional profiles across color categories

Color-category comparisons showed that cool colors produced higher pleasantness than both warm and neutral categories. Although this result diverges from segments of the literature that emphasize the emotional benefits of warm colors, it indicates that, within the present context, cooler hues can effectively support positive valence in therapeutic spaces. No significant difference emerged between warm and neutral categories. The distribution of valence ratings was approximately symmetric with a slight tendency toward pleasantness, suggesting a relatively stable chromatic influence on this dimension. Internal heterogeneity was evident within the neutral category: some hues, such as light cream, showed comparatively favorable emotional profiles, whereas white and black were located at the lower end of the valence range. Thus, "neutral" in chromatic terms does not necessarily imply emotional neutrality or uniform indifference. Overall, all three categories retained the capacity to generate moderately pleasant experiences in group-therapy environments, although cool colors yielded the highest pleasantness levels. Within the warm category, internal variation also appeared, with light brown producing relatively higher valence than other warm hues. This pattern indicates that the emotional impact of warm colors depends on specific combinations of hue, lightness, and chroma rather than warmth as a broad property. On the arousal dimension, cool colors elicited higher activation than both warm and neutral categories, while warm and neutral did not differ significantly. Arousal distributions were left-skewed, with many participants experiencing relatively elevated activation levels. From a design perspective, these patterns highlight the importance of considering how nominally neutral colors interact with other environmental features, such as lighting and materiality, because these interactions may modulate arousal in group-therapy rooms. Neutral palettes cannot be assumed to be emotionally inert; their effects depend on specific chromatic properties and spatial context.

Comparing color-category, single-color, and cluster-level results

Comparison of color-category, single-color, and cluster-based findings shows that, while category analyses yield a broad pattern favoring cool over warm and neutral colors, individual- and cluster-level analyses reveal a more intricate landscape. Within the overarching cool advantage, some cool hues, such as dark green and turquoise green, generated particularly high pleasantness or arousal, whereas certain warm or neutral colors (notably dark red, white, and black) elicited less pleasant or less activated responses. This within- and between-category heterogeneity indicates that color-category analysis provides a useful generalized picture, but individual- and cluster-level analyses are necessary to detect finer-grained differences in emotional response. Taken together, these complementary analytic levels underscore that design decisions should not rely solely on broad categorizations (warm–neutral–cool); instead, the specific emotional signatures of individual colors and their cluster membership need to be taken into account when translating these findings into design guidelines for group-therapy environments.

Contributions of the study

This study offers several methodological and analytical contributions to the investigation and design of group-therapy spaces:

- It isolated wall color as the sole environmental independent variable, enabling estimation of the pure effect of color on emotional responses, independent of materiality or texture.
- It implemented a transparent, reproducible VR-based methodology using a validated nonverbal tool (SAM), balancing experimental control and ecological validity by simulating a realistic group-therapy setting while maintaining precise control over chromatic manipulation.
- It adopted a multilevel, data-driven analytical approach—combining PAM clustering, within- and between-color correlations, and color-category comparisons—that identified distinct emotional profiles and yielded design-relevant patterns for the chromatic configuration of group-therapy rooms.

Conclusion

This study investigated the emotional impact of interior wall color in an immersive virtual reality representation of a group-therapy room. Grounded in the PAD (Pleasure–Arousal–Dominance) framework, using a within-subjects design and nonparametric analyses while isolating wall color as the sole environmental independent variable, it provided an empirical assessment of chromatic influence in therapeutic architectural settings. At the descriptive level, most colors elicited responses within mid-range valence and arousal, with only a subset of hues, particularly light yellow, white, black, and light blue, showing greater dispersion, a pattern consistent with the inferential results. The findings showed that wall color significantly affected valence. Dark green and turquoise green were rated as more pleasant than other hues, and adjusted *p*-values in post hoc tests confirmed that their valence ratings were significantly higher than those of dark red and light red. Although effects on arousal were weaker, the within-color correlation analyses indicated that for dark cream, turquoise green, light blue, light cream, and dark green, valence and arousal increased together, pointing to coherent emotional profiles that are advantageous in group-therapy contexts where both emotional safety and engaged participation are desired.

Beyond single-color analyses, PAM clustering identified seven distinct emotional profiles in the valence–arousal plane, demonstrating that emotional responses to color are not organized along a single continuum but instead follow multiple discrete patterns. Category-level analyses further indicated that cool hues produced higher valence and arousal than warm and neutral categories, although warm and neutral did not differ significantly from one another. Comparisons across color-category, single-color, and cluster levels showed that this cool-category advantage did not manifest uniformly within each category: some cool colors and selected neutrals (for example, light cream) yielded more favorable emotional responses than the category-level trend would suggest, whereas other neutrals such as white and black tended toward lower valence, and at least one warm color (light brown) produced relatively higher pleasantness than other warm hues.

Although basic chromatic responses within the PAD framework reflect general perceptual–emotional mechanisms, the evaluation of wall colors in the context of a group-therapy room depends on users' familiarity with the functional, social, and emotional demands of such settings. For this reason, the study intentionally recruited clients with prior group-therapy experience so that their responses would reflect not only perceptual reactions to color but also its relevance to the therapeutic function of the space. Consequently, the core valence–arousal patterns identified here are expected to generalize to typical users of group-therapy rooms, including clients earlier in treatment.

Consequently, design decisions should attend simultaneously to color category, individual colors, and cluster-level emotional profiles. Together, the findings support a shift from purely aesthetic intuition toward data-informed design strategies grounded in users' emotional responses in group-therapy environments. The integration of immersive VR, a validated nonverbal emotional assessment tool (SAM), and nonparametric analyses demonstrated that emotional responses to color in group-therapy settings can be measured with precision and interpreted as distinct patterns that can inform practice. Overall, the results suggest that a high-valence–low-arousal strategy, whether achieved through specific colors or through clusters with similar emotional signatures, holds promise for enhancing emotional safety and interpersonal openness. Future research could extend this approach by incorporating additional multisensory dimensions, such as lighting, material texture, and acoustic quality, and by testing the applicability of these findings in real-world group-therapy rooms. Such work would help translate emotion-related knowledge into evidence-based architectural design, enabling therapeutic environments to be optimized not only visually but also emotionally.

End Note:

The color dark brown (RGB: 92, 53, 21) has CIELAB values L*=26.38, a*=14.43, b*=26.85; light brown (RGB: 139, 69, 18) corresponds to L*=37.46, a*=26.41, b*=41.39; dark red (RGB: 204, 51, 0) has L*=45.92, a*=58.05, b*=58.16; light red (RGB: 200, 60, 70) has L*=46.92, a*=55.62, b*=26.58; dark yellow (RGB: 255, 192, 0) is defined by L*=81.27, a*=9.87, b*=83.20; light yellow (RGB: 255, 222, 109) corresponds to L*=89.21, a*=−1.69, b*=58.65; dark cream (RGB: 239, 234, 225) has L*=92.85, a*=0.14, b*=4.96; light cream (RGB: 233, 224, 217) has L*=89.69, a*=1.86, b*=4.51; white (RGB: 244, 247, 247) corresponds to L*=97.01, a*=−0.99, b*=−0.35; black (RGB: 61, 60, 58) has L*=25.35, a*=−0.01, b*=1.39; gray (RGB: 128, 128, 128) is defined by L*=53.59, a*=0.00, b*=0.00; dark blue (RGB: 0, 83, 140) corresponds to L*=34.15, a*=1.36, b*=−37.54; light blue (RGB: 175, 219, 244) has L*=85.15, a*=−8.67, b*=−16.87; dark green (RGB: 77, 93, 83) has L*=37.90, a*=−8.41, b*=3.70; green (RGB: 0, 117, 93) corresponds to L*=43.52, a*=−34.42, b*=5.37; turquoise blue (RGB: 0, 191, 254) has L*=72.50, a*=−18.01, b*=−42.07; and turquoise green (RGB: 1, 206, 209) corresponds to L*=75.29, a*=−40.02, b*=−13.51.

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