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Exploring Colour–Pattern Interaction in Textile Design

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ABSTRACT

Colour plays a pivotal role in shaping aesthetic judgment in textile design, influencing emotional perception. This study examines colour-pattern interaction with a focus on colour as a prime determinant using monochromatic textile pattern designs. An empirical survey was conducted to investigate preferences for a range of colours across two design contexts: textile patterns and abstract forms. The perceptual dimensions and emotional reaction to the colours investigated were examined. The statistical analysis indicates that colour is a primary driver of these preferences. The investigation reveals high consistency between sampled young Omani design students' choices of preferred contextless and pattern design colours, indicating an interrelationship between them. Blue exhibited the highest preference, perceived as exceptionally soft, clean, fresh, and relaxing; moderately as classical and heavy; and mildly emotional due to its warmth and activity. Relaxing emotion was the only statistically significant factor in discriminating between preferred colours. The "relaxing" emotion's considerable association with colour preference indicates that the relaxation feature is linked to the preferred colour, namely "Blue". These pilot findings provide empirical insights from young Omani design students, establishing a foundational baseline for future textile research into the interrelationship between pattern and colour in shaping preferences and associated affective emotions. This study contributes to textile design research by revealing the role of colour in pattern perception and the emotional factors that drive preferences, thereby inspiring textile designers to embed colour considerations into the exploration of colour within the pattern context for design-informed aesthetic decision-making.

KEYWORDS

colour, hue, pattern, preference, symmetry

INTRODUCTION

Colour plays a crucial role in shaping human cognitive responses to the surrounding environment and to products, with psychological effects that include preferences and emotions. These evoked emotions can significantly influence human judgment, attitude, or behaviour towards visual designs. These interactions between colour and visual design, as well as the emotional responses to colour, have been studied across psychological, empirical, and theoretical contexts, exhibiting an emotional link between colour and preference, relating colour preference to specific colour groups, and demonstrating how these colours evoke emotions that contribute to this preference [1-3].

Pattern is one of the design principles embedded in various aesthetic applications, including textiles, a “pattern”, in the visual design context, involves creating an organised and structured design in which design elements (such as lines, shapes, or colours) or motifs are repeated and arranged in a structured, predictable, and regularly decorative way to enhance visual appeal [4]. It can be a fundamental element and an exceptional approach for communicating effectively in the decoration of textiles, including overall and border pattern designs that can be used to embellish clothing, fashion, and home furnishings. Pattern is an essential constituent of textile aesthetics, and colour plays a critical role in shaping perceptual and emotional responses to patterned surfaces. Notably, pattern designs are not only aesthetic decorative features; they also intertwine with various values and structures that can shape people’s psychological state.

A review of the existing literature indicates the need for further studies on this topic within colour design psychology, which can contribute to theoretical and empirical research in textile pattern design. This study investigates the significance of colour’s influence on textile pattern design preference, using an identified favoured symmetrical pattern type to examine preferences when presented in different hues. This is facilitated by exploring the preference for colour in pattern design and abstract representation, as well as their relationship. Moreover, colour preferences are discussed in the context of evoked emotions to understand why preferences are attributed. This research examines the attitude pattern design consumers exhibit towards colour and investigates colour's influence on consumers’ psychological impressions, thereby reinforcing its role as an aesthetic expression. This study makes several contributions to textile and fashion design research. It highlights the broader role of colour in shaping emerging consumer preferences

for textile pattern design. It contributes to colour design psychology by highlighting human attitudes and reactions towards abstracted colour and its application in textile pattern design. Additionally, it links inductive perceptual research to visual design practice by situating its findings within the field of applied arts design, with a particular emphasis on textile design applications that utilise colour and pattern as dominant design elements.

LITERATURE REVIEW

Textile Pattern Design

Studying textile pattern design can be traced back to the early 1840s when a treatise on copyright in printed textiles was published in the UK; whereas the protection of textile designs was raised to enhance the character and taste of the produced designs, supporting art and design textile products because it was believed to be a significant method of gaining a competitive advantage [5, 6]. Previous research has recognised the significance of textile pattern design from various perspectives, including psychological perspectives. Culturally, patterns can carry symbolic and semantic values. Several research studies have focused on reviving and reinventing cultural pattern designs [7-10]. Furthermore, Pattern design decisively reflects social status, structures, and belonging to religious or ethical groups and identities. Textile pattern design also affects consumers' behaviour regarding sustainability and moral considerations, and can reflect their environmental responsibility. Brands that integrate meaningful and sustainable pattern design strategies can enhance consumer trust and engagement. In the context of textiles, pattern design reflects personal identity and self-expression. They shape consumer choices, purchasing decisions, preferences, and emotional engagement with products, with design choices contributing to aesthetic experiences and brand loyalty [11].

Pattern design has been employed by designers and investigated by researchers to enhance visual communication and uplift functionality in textile designs. Capron and Huysmans (2003) concluded that using colours on furnishing textile surfaces can improve children's well-being by adding a tactile dimension, modifying depth perception, and rescaling rooms for spatial anchoring and concentration [12]. Long et al. (2009) found that fractal pattern art is prosperous and versatile, ensuring fashion design is widespread and accepted among consumers [13]. Later, Gong & Shin (2013) highlighted the importance of texture in

distinguishing textile pattern design [14]. A 2024 study by Jamil and Ijaz explored abstract art as a source of inspiration for textile pattern design and found that marbling, in particular, could be a versatile source for such design [15]. Consequently, design researchers investigated consumer attitudes and preferences regarding pattern-seeking outcomes, thereby supporting designers and researchers in the textile and fashion fields.

Pattern Design Structure

Pattern design follows a set of rules, such as grid or network structures, symmetry, or tessellation. These structures would employ one or a combination of networks of simple or complex shapes, such as Squares, Bricks, half drops, Diamond Triangles, ogees, hexagons, or scales [4]. Research studies have highlighted the potential for perceiving beauty from various perspectives and at multiple levels of recognition [16]. Moreover, aesthetic judgement encompasses multifaceted perspectives, including social and ethical dimensions, underscoring the importance of symmetry and the complexity of visual art and design [17]. One design theory approach is to create methodologies that classify designs and systematise their creation process [18]. Therefore, 17 symmetry pattern types were initially developed by Woods, H. J., in 1930 (according to Hann) [19]. Symmetry Types used in pattern design were classified into 17 overall and 11 border classes. Moreover, pattern design—like all types of visual design—is created using design elements and applying visual design principles, including repetition, symmetry, unity, and rhythm, which serve as guidelines for creating artwork and designs. These significant and versatile art and design principles work together to create aesthetically pleasing patterns that convey cohesion, consistency, and unity throughout a work of art or design. Although pattern design may seem uncomplicated, previous studies have examined it in depth from multiple perspectives due to its uniqueness and importance across various design applications, including textile and fashion design. Several studies have investigated the psychological aspects of pattern design and examined the effects of pattern design elements on emotional responses and perceptual interpretations [11, 18-21]. Therefore, pattern symmetry can serve as a gateway to beauty, which is why it is studied in this research.

Colour in Textile Pattern Design

Colour is a key design element in textile pattern design, significantly impacting consumer attitudes and purchase decisions. It significantly affects the overall visual impression and can influence consumers' recognition and interaction with a design [22-24]. It is a potent visual stimulant that can influence aesthetic appeal, elicit psychological associations, and transmit cultural meanings. Previous research studies have concluded that it is the most effective design element, influencing 90 per cent of purchasing decisions within 90 seconds [25].

In 1939, Lark-Horovitz studied children's preferences for pattern design and examined 39 textile patterns, including original and large-sized modern and historical designs. The three most liked patterns—in terms of colour—were white, black, grey, lemon yellow, green, red, rust, pink, and sky blue. Pattern shapes were elephant heads, spirals, leaves and flowers, diamonds, steps, and crosses [26]. In 2006, Homolong studied the ways consumers describe colours and pattern compositions. Patterns investigated included old Amish quilts, whose colours were analysed and represented in the NCS space. The designs featured blue-striped patterns on a white background, eschewing figurative and naturalistic motifs. Participants' selections for preferred patterns were linked to formal, functional, cultural, and emotional content [27]. Takagi et al. (2012) conducted a comparative study of US and Japanese consumers' attitudes toward textile colour and pattern, finding that culture influenced colour preference. However, culture, age, and gender also influenced preferences in pattern design. Colour differences were more apparent than pattern design preferences [21]. Hsu et al. (2016) examined the colour preferences of five Taiwanese floral-pattern fabric designs, which were the base designs recoloured using the 35 colours primarily used to colour Taiwanese patterns, yielding 175 coloured designs. Two factors dominated preferences for the tested designs: splendour and harmony. Interestingly, this research found that the "liking" factor does not impact the impression that the pattern is Taiwanese. However, factors influencing Taiwanese consumers' colour preferences for fabrics included colour and pattern combinations, liking, and user experience [20]. Therefore, from a theoretical background, several studies have explored the impact of colour design across various contexts, including pattern design.

METHODOLOGY

This study employed an inductive approach, starting with the identification and preparation of stimuli for the investigation, followed by a survey exploring consumers' responses to colour in pattern design and in contextless settings. The final step in the analysis was to examine emotional responses to the favourite context-free colour to highlight the emotions underlying preference. After collecting the primary data, the next step is to conduct statistical analysis to obtain descriptive and inferential statistics. Figure 1 illustrates the research development process, beginning with the theoretical background and culminating in the findings.

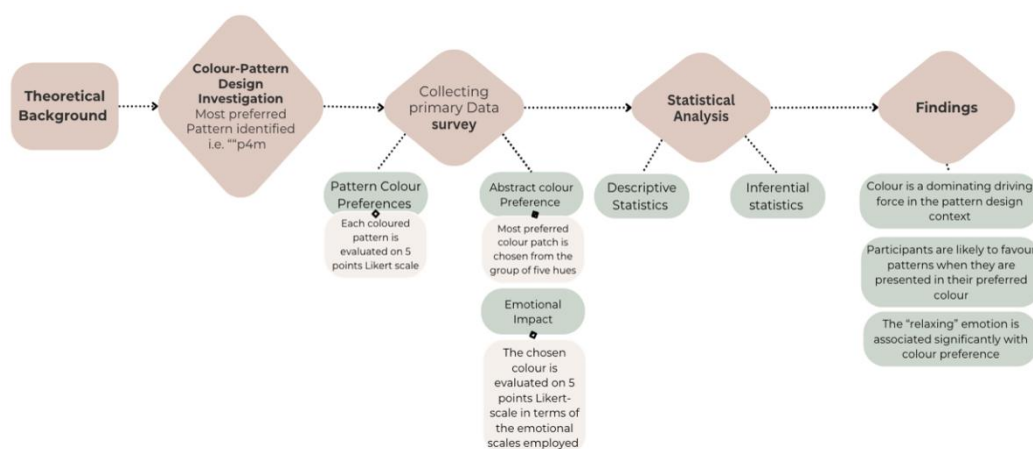


Figure 1. Research Development Process

Stimuli Specification

Pattern Design Selection

One pattern is employed in this study to isolate the impact of structural variation on the perceptual influence of colour. The selected pattern is of symmetry type p4m, a significant structural pattern widely adopted in traditional textile designs and preferred [18, 28-31]. This class is characterised by a hexagonal or square lattice of the highest rotation order, three or higher; the generating region is 1/4, 1/6, 1/8, or 1/12 of a unit. A pattern created within this symmetry class has the smallest rotation of 90°, includes a glide reflection along lines intersecting at 45°, and has rotation centres on the reflection axis [19]. Therefore, the colour variation was neutralised in an earlier study, and only the pattern structure was examined to identify the preferred type. Maintaining a single pattern while varying the colours used minimizes the confounding

effects of contradictory influences arising from the complexity of colour and pattern variation and provides a controlled environment and a clear baseline for investigating colour perception and interaction within the identified structured tiling, rather than within organic patterns. Consequently, a symmetry-type pattern design, i.e., p4m, is used in this study as a controlled class (shown in Figure 2).

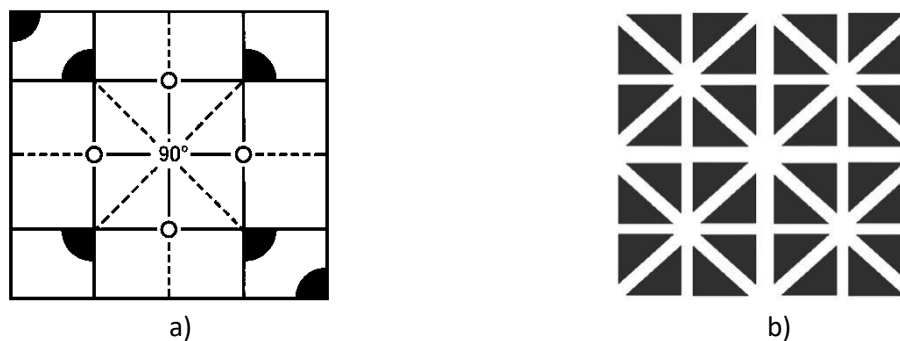


Figure 2. Symmetry class “p4m” is identified as the most preferred (a) Schematic illustration adapted from Hann, 2003 and Hann & Thomas, 2010; (b) Design Created adapted from Sanad & Hanafy, 2017 [18, 19, 32]

Colour Range Identification and Standardisation






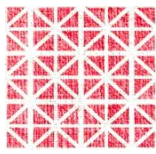
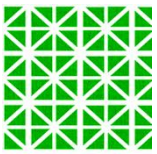
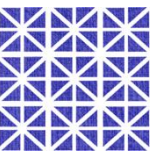
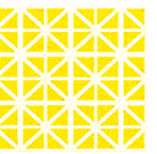
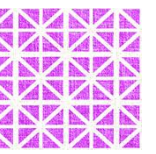
Five pure hues, at their maximum saturation and brightness levels, namely red, yellow, green, blue, and magenta (see Table 1), were used as primary aesthetic independent variables to recolour the investigated pattern, creating textured, textile-like designs in Photoshop. These colours correspond to the five principal hue classes (R, Y, G, B, P) of the Munsell colour system and have been used in various colour design research studies as the basis of colour range selection. Using Photoshop software, the hues were kept at maximum brightness and saturation by setting their RGB values to 255 or 0, respectively, ensuring that hue was the only variable, as required to avoid complexity in perceptual experiments and to fix hue as the independent variable. It is noteworthy that our labelled colour Magenta corresponds (and not to) Munsell’s Purple; however, it is the most chromatically saturated approximation in the RGB colour space and is repeatedly used in colour design studies [33, 34].

This practice of using pure hues aligns with prior research prioritizing chromatic purity, investigating colour preference in various design contexts, which employed only hues to isolate their effects and prioritized chromatic purity over brightness equalisation [33, 35, 36]. Moreover, it has been empirically demonstrated that hue preference curves do not vary significantly across different lightness and saturation levels [37] and that colors with maximum saturation and brightness are most preferred [38]. Moreover, this range of pure

hues ensures that the recorded responses represent the sampled participants' aesthetic judgments, achieve maximum and consistent contrast across stimuli, maintain a clear distinction between color categories, prevent the complexity of lightness variations in perceptual experiments, ensure ecological validity in the design context, and ensure consistency, reproducibility, and experimental control across digital display devices on which the current study's digital/online survey is conducted. It is noteworthy that this adopted approach to stimulus development can help control the visual intricacy that would otherwise arise from pattern variations and isolate the impact of colour, enabling a more reliable interpretation of its psychological effects. Furthermore, this study is a step toward a deeper exploration of design-informed aesthetic preferences for colour and their relationship to pattern design.

The coloured patterns used in the current study were employed solely to examine sampled student demographic preferences; however, the emotional investigations were conducted independently using abstract colour patches, so affective responses were elicited solely by hue rather than by pattern structure. This means that any expected Illusory effects were tackled in emotional tests.

Table 1. RGB colour values used in recolouring the pattern design are identified

Colour name	Red	Green	Blue	Yellow	Magenta
Colour Patch					
Coloured Pattern design					
Colour Values on RGB Model	R	255	0	0	255
	G	0	255	0	255
	B	0	0	255	255

Questionnaire Design

An online survey was conducted to collect primary data; however, to ensure experimental control, the visual stimuli were presented via a centralised digital projector (Hitachi CP-EX252N) connected to the researcher's workstation. This approach was adopted to provide a unified visual baseline and to compensate for potential limitations in individual device calibration. It is noteworthy that previous research

has validated the use of digital media as a reliable proxy for physical colour samples [34, 39], and Yu et al. found a strong correlation between physical (laboratory) and (online) experiments examining colour [33]. Consequently, these studies validate the reliability of transferring colour data across digital stations and platforms; they demonstrate that participant colour preferences remain consistent whether viewed on a controlled workstation or on a digital projection. Therefore, it is believed that the online survey, supported by this cross-platform digital stability, effectively maintains the reliability required for the current research. The first section of the survey includes two questions about the sampled young Omani designers' information: minor specialisation and level of study. Each participant should answer these two questions by selecting the appropriate answer from the listed choices. The minor specialisations listed are Interior design and graphic design. Then the student is asked to identify her level of study, from 1 to 4, for any of the minors. The second section of the survey examines the sampled cohort's preferences for the coloured patterns design. Therefore, each sample is assessed and given a rating of 1 to 5 based on a participant's preference (see the coloured pattern design used in Table 1), as measured on a five-point Likert scale. Rate 1 indicates a low preference level, while rate 5 indicates a high one. The third section of the survey explores the sampled student demographic colour preferences, regardless of pattern design, i.e., contextless colour preference. Therefore, five colour patches—shown in Table 1—are displayed together for the participant to select the one they prefer most. Then the participant is automatically directed to the fourth and final section, which asks about the emotional impact of the chosen colour. Noteworthy that “preference” questions in the second and third sections employed rating with “stars” ★★★★★ icons by highlighting the number of stars indicates their level of preference to facilitate the sampled cohort's responses, because this is how they valued online purchased items. Hence, they are aware of using this method.

The survey's fourth and last section focuses on the emotional effects of the preferred colour. This uses eight emotions: heavy, classical, clean, active, fresh, soft, relaxed, and warm. This group of emotions was originally structured by Osgood et al. [40] and later adopted by other researchers [1]. Osgood et al. categorised these eight emotions into three groups based on their literal meanings: evaluative (E), potency (P), and activity (A) factors. Clean, fresh, and like/prefer are from the evaluative group, heavy and soft belong to the potency factors group, and classical, active, relaxing, and warm belong to the activity group [1, 40]. Osgood et al. investigated various concepts and found that these three factorial categories are the

most stable and effective. The evaluative factor explained 50-75% of the total variance of semantic space, indicating its significance. However, both Potency and activity factors account for 50% of the total variance. This EPA model served as a valid base structure for the affective meaning in semantic space [40]. Therefore, this study adopted this identified group of emotions.

Therefore, in this section, sampled student demographic were asked eight questions to rate the already selected colour as the most preferred among the five colours examined on a five-point Likert scale. The rating is regarding the extent to which sampled design students found the colour: "Heavy", so rate 1 means a very light level, while rate 5 indicates a weighty one, "Classical", so rate 1 means a very modern level, while rate 5 indicates a very classical one, "Active", so rate 1 means a very passive level, while rate 5 indicates a very active one, "Fresh", rate 1 means a very stale level, while rate 5 indicates a very fresh one; "Soft", rate 1 means a very hard level, while rate 5 indicates a very soft one, "Relaxing", rate 1 means a very Tense level, while rate 5 indicates a very relaxing one, finally "Warm", so rate 1 means a very Cool level, while rate 5 indicates a very warm one. Each emotional question used a rating with a "thumbs-up" 👍👍👍👍 icon to ease the participant's responses by highlighting the number of thumbs indicates their level of agreement that these colours evoke emotions.

In this survey, all questions were translated into Arabic, the native language of all students. This was done to avoid misunderstandings, especially since Arabic is the language of instruction and learning. The original emotional terms employed in this study were first translated from English into Modern Standard Arabic using the Al-Mawrid dictionary, which is widely used for translation studies (Al-Ajmi, 1992; Lecheheb, 2024). This translation was conducted by a bilingual researcher with expertise in art, design, and colour terminology in Arabic and English. Following this process, a back translation is performed independently to translate the obtained translations into British English using DeepL Translator, which is considered in research studies to be a traditional translator with powerful capabilities to develop human-like, reliable translations (Gao et al., 2024; Macketanz et al., 2020; Telaumbanua et al., 2024; Zalikha, 2024). It is noteworthy that the back-translation reproduced the original English terms. Then, both English and Arabic word lists were reviewed by a bilingual expert in art and design, with a focus on colour, to confirm conceptual equivalence. Finally, the final Arabic terms were used in the survey instrument. Besides, the

colour names were displayed alongside the colour patches in section three to indicate the perception of the colours, mainly because the colours are explored as hues with no chroma or value variations.

Participants

This study is a pilot exploratory investigation focusing on a cross-section of female Omani design students to obtain preliminary insights into colour–pattern perception within a homogeneous emerging consumer group, providing an empirical baseline for future large-scale research. This sampling method makes this study an initial step toward a larger experimental study. Undergraduate students in the design department of Al Zahra College for Women in the Sultanate of Oman, enrolled in interior and graphic design programs, were invited to participate in the online, self-administered survey. Moreover, the pattern used in the current study was previously investigated as a black-and-white design in a survey that recruited participants sample from similar cultures, ages, and genders, and with similar specialisations. Hence, conducting a study of a similar population sample would support practical and logical comparisons and implications.

The current study is designed sequentially to clearly distinguish colour preference from the emotional responses associated with it. First, the preference for coloured patterns created using five different hues is examined. Secondly, the most preferred abstract colour was determined by the sampled design students' selections from a group of colours representing those used to colour the patterns. After selecting the most preferred abstract colour, the sampled cohort is automatically directed to a set of questions about their emotional reactions to that colour. It is noteworthy that the correlation between both preferences, namely pattern and abstract colour preference, is investigated.

The visual context was stabilised by maintaining a fixed, orderly presentation of hues following a spectral progression within or across questions. This approach is adopted rather than randomization to achieve a fully uniform stimulus environment by maintaining constant contextual relationships that prevent judgments from being influenced by changing adjacencies and sequences; this ensures selections are based on inherent color preference and attitude, reflects a high degree of inter-subject comparability, and minimizes the risk of relational bias skewing the frequency distribution. Furthermore, this order reduces visual dissonance and minimizes cognitive load, allowing the eye to transition smoothly between hues to align with standard textile colour communication and provide ecologically valid preliminary pilot findings.

RESULTS

The following findings represent the aesthetic preferences of the sampled student demographic and serve as preliminary indicators describing the perceptual impact of color, specifically within the framework of the p4m symmetry group for the wider Omani textile design context.

Participants' Responses

In this study, 74 students participated in the survey: 56 (75.7%) were from the graphic design program, and 18 (24.3%) were from the interior design specialisation. Regarding study levels, the students were from the first, second, third, and Fourth levels, with the following percentages: 25.7%, 4.1%, 52.7%, and 17.6%, respectively. Most students (70.3%) were from the advanced levels of study, namely the third and fourth years. Additionally, Graphic design students outnumber interior design students at all levels of study. Figure 3 shows the distribution details of the students who participated in the survey.

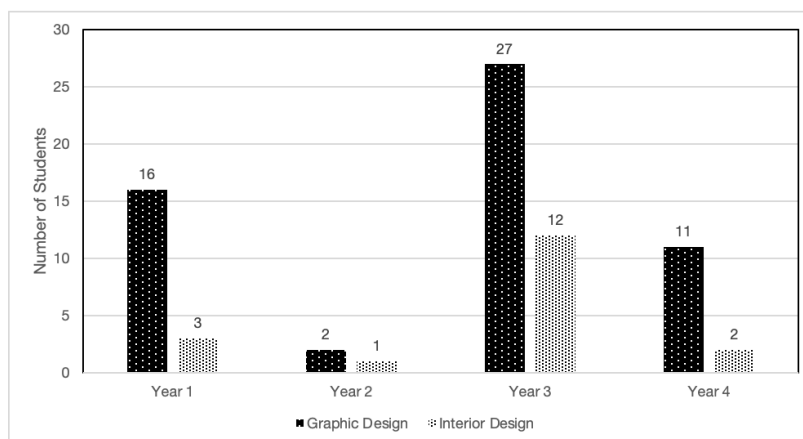


Figure 3. Distribution of Students participated in the survey (Year of study and Specialisation)

Preference for Coloured Pattern Designs

Design student-led sample preferences for the specific symmetry class, coloured blue, green, yellow, red, and magenta, were evaluated using a five-point Likert scale, where 1 indicates the lowest preference, and 5 indicates the highest preference. The sampled young Omani designers rated each coloured pattern studied, and the sum scores for each of the p4m configurations were calculated by multiplying each rating's frequency by its respective Likert score, producing the weighted total scores presented in the stacked

column chart (see Figure 4a). Each bar is coloured with five various tones of its colour; i.e., the lighter the tone, the lower the rating, and vice versa, the darker the tone, the higher the rating. This visualisation helps easily link the presented ratings to the relevant colour. Additionally, the mean ratings of the colour geometric p4m grid were calculated to measure the central tendency of the ratings (see Figure 4b). Error bars in Figure 4b represent ± 1 standard error of the mean, calculated to indicate the variability and precision of observed preference ratings for each coloured pattern studied.

Figure 4a shows that rating 5 had the highest frequency across all coloured p4m patterns compared to rating 1, which has a low frequency, demonstrating a low preference. The blue pattern studied scored the highest frequencies at ratings 5 and 4 on the Likert scale and received the fewest sum scores at ratings 1 and 2. At a rating of 3, it falls within the mid-range frequency. The yellow and green p4m configurations followed the blue one in terms of the sum rating scores. However, according to level 5 ratings, they are ranked second and third, respectively, with the highest scores. The green slightly exceeds the yellow p4m pattern at the rating Levels 4, 3 and 2. The least preferred coloured p4m grid is magenta, followed by red, which is marginally higher than magenta. Magenta and red p4m patterns are more prevalent in medium and low ratings than at the highest level.

The overall preference trend among the design student-led sample for each coloured p4m pattern was explored using mean ratings to understand the observed strength of each colour and compare all of them. The mean ratings of the specific p4m-based stimuli were as follows: blue ($M = 3.7$, $SE = 0.14$), closely followed by green and yellow ($M = 3.2$ for each, $SE = 0.15$ and 0.16 , respectively). The red and magenta p4m layouts are ($M = 2.9$ and $M = 2.8$, respectively). Regarding the data precision of sample means, generally, SE bars are relatively steady across all colours. However, it was found that the yellow and magenta data had wider error bars.

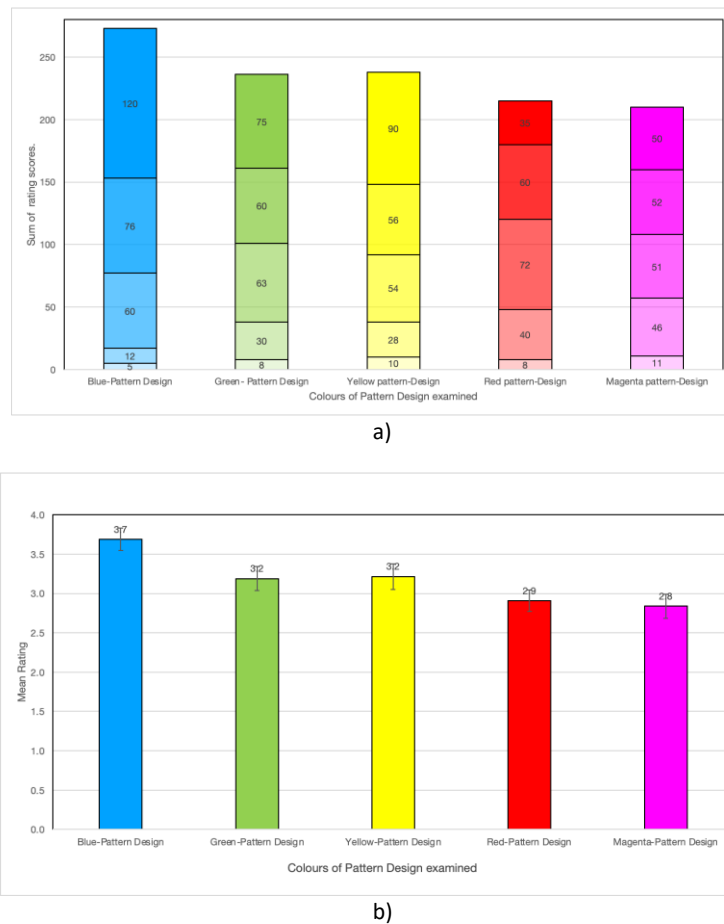


Figure 4. The sampled design students’ preferences for Coloured pattern (a) Distribution of Colour Pattern Design Preference Ratings; (b) Colour Pattern Design Mean with ± 1 SE

Preference for Abstract Colours

In this section, abstract colour preference among the sampled young Omani designers was studied independently of the p4m configuration to gain a deeper understanding of the influence of the cohort’s colour preference on their choice of colourful p4m grid designs. Each participant was asked to select the most preferred colour from a group of colour patches presented. Figure 5 presents the selection frequency of the most preferred colour; 35 participants (47.3%) selected blue. Magenta, then, is followed by Yellow, with 14 (18.9%) and 13 (17.6%) participants, respectively. Red has significantly low frequencies, with 8 (10.8%). The least preferred colour is green, which was selected by 4 (5.4%) students, respectively.

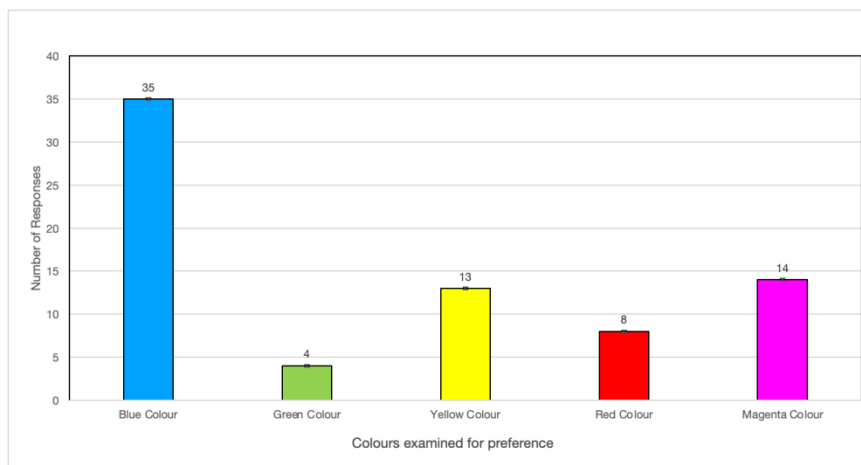


Figure 5. Frequency of Colour Preference

Association Between Colour Preference and Pattern Preference

Ranking of Colours and Pattern–Colour Combinations

This section examines the correlation between the preference for contextless colours and coloured p4m-based stimuli. From the previous sections, the ranking of coloured p4m layout preferences is Blue > Yellow, Green > Red > Magenta; however, the order of colour preference ranking is Blue > Magenta > Yellow > Red > Green. By investigating and comparing the preference ranking of colours and their p4m grid, it was found that Blue remained steady in its first rank as the most preferred as an abstract colour and in the context of p4m tiling. Moreover, Red is secured in fourth place, indicating a low preference for the colour and within the p4m framework. The yellow preference level slightly changed from the second rank as a p4m symmetry to the third rank as a colour. The interesting cases are of magenta and green. Green moved from the second most preferred within the p4m framework to the least preferred colour. Moreover, Magenta advanced its rank from being the least preferred p4m pattern to the second favourable one.

Consistency of Colour Preference

This section focuses on examining the consistency between choices of colour and the p4m-based stimuli preferences. The colour consistency rate (CRR)— used by Yu et al. in 2018 and later employed in several research studies—is adopted to statistically explore the consistency of participants' preferred colour patches and p4m symmetry designs [33, 34]. CCR is the percentage of subjects whose preferred colour matches one of the highest-rated p4m grid colours. A participant's preference is considered consistent if

the favourite colour selected was found to match any of the colours that received the highest rating (i.e., the maximum Likert score) in the colour p4m configuration survey. This comprehensive approach of rating more than one specific p4m layout and matching the ratings with sampled design students' abstract colour selection recognises the individuals' ability to express equal preference for more than one colour, rather than being compelled to select a single p4m pattern design as the most preferred.

Figure 6 presents the colour consistency rates (CCR) of the five examined colours. The bottom (solid) part of the column chart presents the consistent percentage; however, the upper parts of the columns (striped) show the inconsistent rates, and the black horizontal dotted line represents the threshold of CCR. The threshold of CRR equals the percentage of each colour of the explored ones. Because this study examines the five colours, the CRR threshold is 20% (marked with a dotted horizontal line in Figure 6). The percentage of students having matched colour patches and p4m-based stimuli is calculated for each preferred colour. These percentages were then compared with the computed threshold CRR. Colour choices are considered consistent if a colour's CRR exceeds CRR (20%), indicating high agreement in the sampled cohort's preferences. CRRs are calculated for the five colours and presented in Figure 6. The CRR values for yellow are 69.2%, 60% for Blue, and 50% for green, red, and magenta. The strong correlation between the preference for coloured p4m-based grid and abstract colour indicates that the visual illusion, such as the Herman grid illusion, has not affected the preference examined.

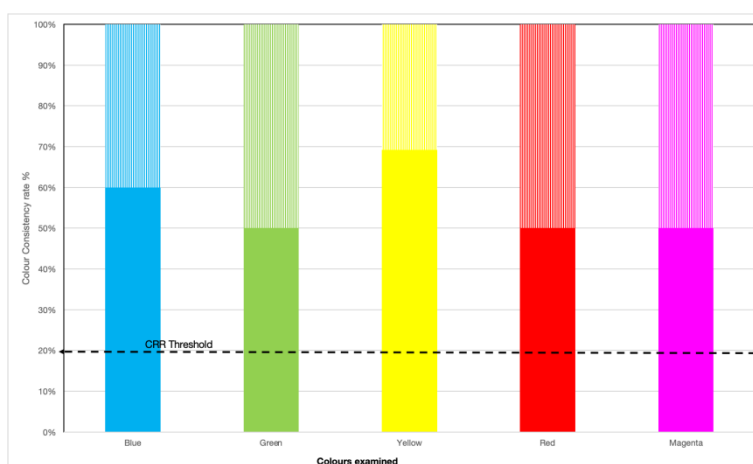


Figure 6. Colour consistency rates (CCR) of the five examined colours.

Emotional Responses to Colour

The emotional impacts of the colours selected as the most favourite are explored, as an approach to relating the colours’ expressive emotion to the chosen colours and then to the coloured p4m symmetry grids. Each participant, after expressing a preference for one of the five colours examined, was directed to the last section of the survey, where they were asked to rate the emotional impact of the selected colour on a 5-point Likert scale. The emotions explored were heavy, classical, clean, active, fresh, soft, relaxing, and warm.

Figure 7 presents the frequency of responses and ratings for the sampled young Omani designers for each colour on the 5-point Likert scale. Each bar stacks the recorded responses of all colours for a single emotion, and each segment of the bar is coloured with an appropriate tone to the relevant colour presented by that segment in terms of colour and rating level, i.e. high rank selections are coloured with the darkest tone of the appropriate colour’s data subset and vice versa.

The emotional scales, clean, fresh, active, and relaxing, received high response levels (4 and 5 on the Likert scale) for these emotions. However, heavy, soft, classical, and warm emotions evoke similar low-level responses.

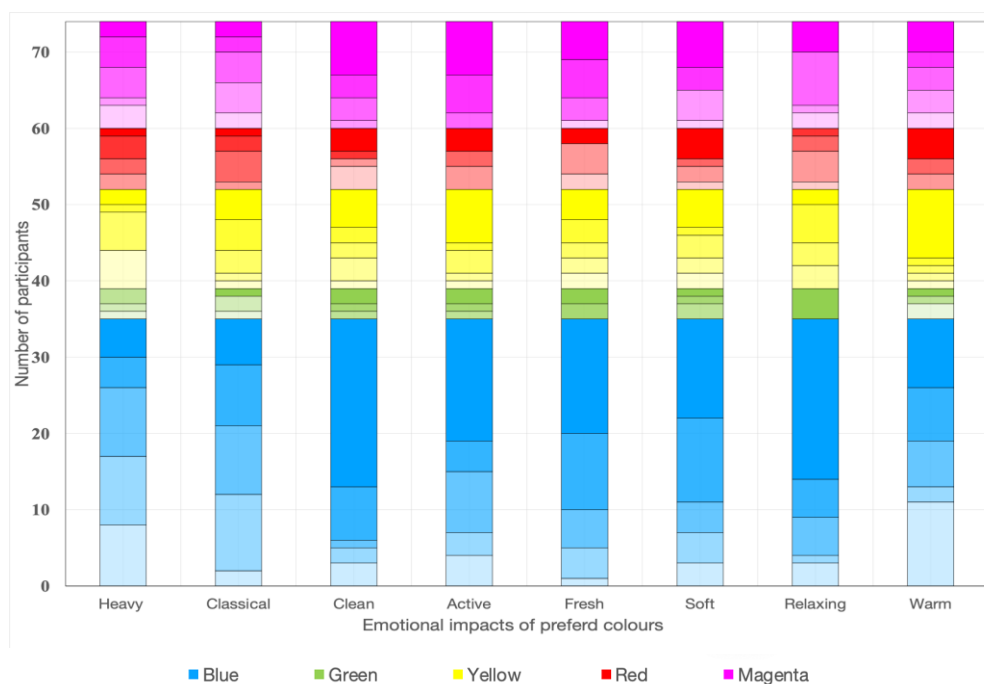


Figure 7. Distribution of Emotional Impacts by Colour Preference

The emotional impact of the explored group of colours was assessed using a Likert scale, which produced varying frequencies across colours. Therefore, the weighted mean scores were used to reflect sampled cohort's responses and accurately consider the extent to which emotions affected them. Weighted means were adopted to account for the varying sample sizes (by correcting for differing numbers of responses) due to the variation in sampled cohort's preference tendencies, which is reflected in the emotional dimension. Therefore, the weighted means are adopted to reflect a more realistic image of the emotional reactions to colours. Table 2 lists statistical data obtained for the statistical analysis conducted, i.e. Response numbers, Median, First Quartile (Q1), Third Quartile (Q3), Interquartile Range (IQR), % Likert 5 and Weighted Mean.

Figure 8 presents the weighted means calculated for the emotional impacts of colours. Two evaluative factors, clean and fresh emotions, were found to rank the colours in a similar order. Green was the highest perceived on both scales, followed by blue, magenta, yellow, and red, with red being the least perceived as clean or fresh. These recorded responses reveal that the evaluative factors, namely clean and fresh, are recognised positively, particularly with cold colours, and vice versa-

However, green was the least perceived colour as either classical or warm. Classical emotion ranked colours as follows: Yellow>Red >Blue> Magenta > Green, and on the warm scale, colours were ranked as follows: Yellow >Red > Magenta> Blue> Green. For the potency emotional factors, namely heavy and soft, the heavy emotional scale ranked the colours as Red>Magenta>Blue>Yellow>Green.

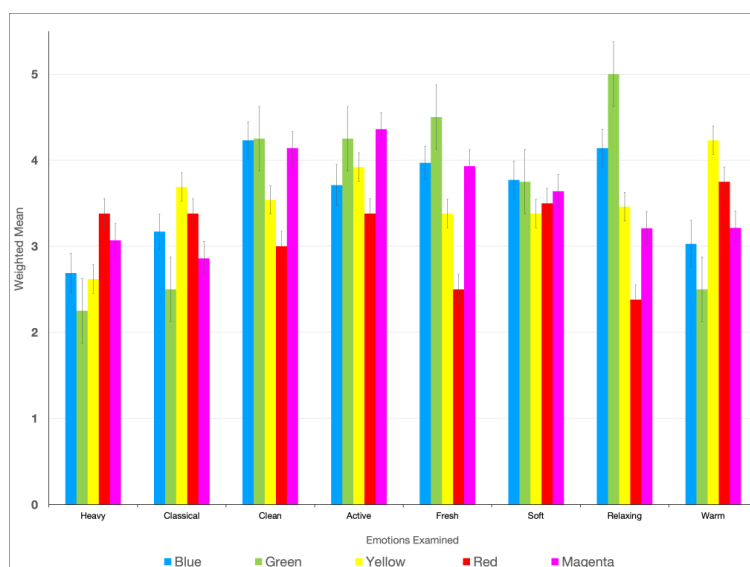


Figure 8. Weighted mean of examined colours' emotions

A non-parametric one-way ANOVA on ranks test, the Kruskal-Wallis test, was conducted to validate the findings, especially considering the possibility that the collected data might not fulfil normality. Therefore, for each of the eight emotions examined (dependent variables), the sampled design students' emotional responses and differences in their preferences for the colours (independent variables) were investigated. The critical value from the Chi-square distribution returned 9.48. Therefore, the null hypothesis is rejected if $H > 9.48$ and fails to reject if $H \leq 9.488$ (see Table 2 for the Kruskal-Wallis one-way analysis-of-variance test-calculated H values). Based on the findings, the relaxing emotional scale was statistically significant, with $H = 18.1640$, $p < 0.01$. Warm is close to the critical H value, but still insignificant.

A post-hoc test for Kruskal-Wallis, the Dunn's Test, is conducted to examine pairwise differences in perceiving relaxing emotion among explored colours. In this test, Z-scores were calculated and compared to the Z-critical value (± 2.807) at Bonferroni-corrected $\alpha = 0.005$, where $|Z| > 2.807$ is considered significant (Table 3 lists calculated Z-scores). Table 3 shows that Green is significantly more relaxing than other colours ($Z = -6.39$ to -9.36 , $p < .005$). Blue is more relaxing than Magenta, Red, and Yellow ($Z = -3.26$ to 6.24 , $p < .005$), but less than Green ($Z = -3.13$, $p < .005$). Furthermore, magenta and yellow are more relaxing than red, but the difference is not statistically significant ($Z = -0.36$, $p > .005$), indicating similar effects on the relaxation emotional scale. Finally, Red was the least relaxing colour ($Z = -3.34$ to -9.36 , $p < .005$).

The Kruskal-Wallis test identified the relaxing "emotional" scale as a crucial scale in relation to p4m-based coloured-stimuli preference, as it is statistically significant ($H=18.16$, $p<0.05$). Although, from the descriptive statistical data of all examined emotional scales, Green (N=4) is found of high mean on the realxing and active in the activity dimension; besides clean, fresh in the evaluative dimension, the Blue (N=35) achieved high weighted mean across several several emotioanl scales namely Heavy and Soft (from Potency factors group) and classical and warm (from Activity group). Therefore, the findings provide evidence that Blue findings are the most statistically powerful for the study's conclusion.

DISCUSSION

In this study, a survey was conducted among students enrolled in advanced design programs, indicating extensive exposure to colour design and theory courses that explore colour meanings and the emotions

they evoke. This suggests that the questionnaire's sample of young Omani designers has a good understanding of the research field.

The data obtained indicate that sampled Young Omani designers held a positive attitude toward coloured p4m configurations. However, the blue p4m layout received the highest weighted total score, suggesting a strong relative preference compared to other colours. The sampled cohort's choices showed balanced distributions across high- and mid-range scores, indicating that the green p4m symmetry was considerably preferred, followed by the yellow p4m pattern. The tendency towards the yellow p4m grid indicates its agreeability among the sample of participants. Furthermore, the obtained statistics indicate a low tendency for the sampled student demographic to prefer red and magenta studied p4m patterns.

Table 2. Colours' emotional responses' Mean, Weighted mean and Weighted sum scores

Colours	Statistical data	Heavy	Classica	Clean	Active	Fresh	Soft	Relaxin	Warm
Blue	Responses No	35	35	35	35	35	35	35	35
	Median	3	3	5	4	4	4	5	3.00
	First Quartile (Q1)	2	2	4	3	3	3	3.5	1.00
	Third Quartile (Q3)	3.5	4.0	5.0	5.0	5.0	5.0	5.0	4.50
	Interquartile Range (IQR)	1.5	2.0	1.0	2.0	2.0	2.0	1.5	3.50
	% Likert 5	14.3	17.1	62.9	45.7	42.9	37.1	60.0	25.71
	Weighted Mean	2.69	3.17	4.23	3.71	3.97	3.77	4.14	3.03
Green	Responses No	4	4	4	4	4	4	4	4
	Median	2.5	2	4.5	4.5	4.5	3.5	5	2.00
	First Quartile (Q1)	1.75	1.75	3.75	3.75	4	3	5	1.00
	Third Quartile (Q3)	3.0	2.8	5.0	5.0	5.0	4.3	5.0	3.50
	Interquartile Range (IQR)	1.3	1.0	1.3	1.3	1.0	1.3	0.0	2.50
	% Likert 5	0.0	25.0	50.0	50.0	50.0	25.0	100.0	25.00
	Weighted Mean	2.25	2.50	4.25	4.25	4.50	3.75	5.00	2.50
Yellow	Responses No	13	13	13	13	13	13	13	13
	Median	3	4	4	5	4	3	4	5.00
	First Quartile (Q1)	1	3	2	3	2	2	3	4.00
	Third Quartile (Q3)	3.0	5.0	5.0	5.0	5.0	5.0	4.0	5.00
	Interquartile Range (IQR)	2.0	2.0	3.0	2.0	3.0	3.0	1.0	1.00
	% Likert 5	15.4	30.8	38.5	53.8	30.8	38.5	15.4	69.23
	Weighted Mean	2.62	3.69	3.54	3.92	3.38	3.38	3.46	4.23
Red	Responses No	8	8	8	8	8	8	8	8
	Median	3.5	3	3	3	2	4	2	4.00
	First Quartile (Q1)	2.75	3	1	2	1.75	2	2	2.75
	Third Quartile (Q3)	4.0	4.0	5.0	5.0	2.8	5.0	3.0	5.00
	Interquartile Range (IQR)	1.3	1.0	4.0	3.0	1.0	3.0	1.0	2.25
	% Likert 5	12.5	12.5	37.5	37.5	25.0	50.0	0.0	50.00
	Weighted Mean	3.38	3.38	3.00	3.38	2.50	3.50	2.38	3.75
Magenta	Responses No	14	14	14	14	14	14	14	14
	Median	3	3	4.5	4.5	4	4	3	3.00
	First Quartile (Q1)	2.25	2	3.25	4	3.25	2	3	2.00
	Third Quartile (Q3)	4.0	3.8	5.0	5.0	5.0	5.0	4.5	4.75
	Interquartile Range (IQR)	1.8	1.8	1.8	1.0	1.8	3.0	1.5	2.75
	% Likert 5	14.3	14.3	50.0	50.0	35.7	42.9	28.6	28.57
	Weighted Mean	3.07	2.86	4.14	4.36	3.93	3.64	3.21	3.21
Kruskal–Wallis H	3.3707	4.5812	4.4278	2.6002	6.9642	0.4228	18.164	7.3795	
K W Significance	x	x	x	x	x	x	ü	x	

Table 3. Z scores calculated in Dunn's test for groups of relaxing emotional impacts

Compared pairs			Z score	P value
Magenta	VS	Blue	-3.26	p<.05
Magenta	VS	Red	2.98	p<.05
Magenta	VS	Yellow	-0.36	p>.05
Magenta	VS	Green	-6.39	p<.05
Blue	VS	Red	6.24	p<.05
Blue	VS	Yellow	2.90	p<.05
Blue	VS	Green	-3.13	p<.05
Red	VS	Yellow	-3.34	p<.05
Red	VS	Green	-9.36	p<.05
Yellow	VS	Green	-6.03	p<.05

The weighted total or cumulative preference score suggests that blue and yellow received the highest scores on the Likert scale's high ratings, compared to red and magenta. The mean ratings of the five coloured p4m-based stimuli indicate that blue is the most preferred colour; however, red and magenta indicate low preference among the sampled cohort. The precision data for all colours indicate similar dispersion responses, which support comparisons across the coloured p4m configurations explored. However, the yellow and magenta data indicate more variability than the red and blue p4m grids. Therefore, the colour p4m-based stimuli preferences could be ranked from highest to lowest preference as follows: Blue > Yellow, Green > Red > Magenta. Interestingly, the sampled cohort had previously agreed to favour an investigated p4m tiling, which alternated black and white foreground and background colours [18]. However, colour appeared to influence sampled design students' preferences and tendency towards the same p4m structure differently, as reflected in the ratings of colour p4m configurations, which showed that the sampled cohort's preferences shifted when colour design was involved.

Blue was selected by around 50% of the sampled cohort, showing it as the most preferred colour. Magenta was the second most preferred colour, which aligns with the theoretical background, indicating that this colour held a high rank [11]. The colour preferences suggest its ranking from highest to lowest preference as follows: Blue > Magenta > Yellow > Red > Green. These findings are consistent with previous studies that found blue to be the most preferred colour [1, 2, 33, 41].

The current research findings indicate that Blue is the most preferred colour by the the sampled cohort, but with a lower tendency within the p4m framework rather than a colour. Within the sampled cohort, abstract independent colour preference was dominated by cold colours, Blue and Magenta, which was not true for

warm colours, namely Yellow and Red. These findings highlight the importance of studying colour in relation to design preference and its contextual application. This is because of possible changes that could occur in the sampled cohort's attitudes towards colour in different contexts. However, the fact that blue remains the preferred colour in all contexts demonstrates the strong trend of this colour. This aligns with previous research studies, which indicate that the sampled cohort strongly prefer blue [1, 2, 33, 41].

Colour preference consistency rates suggest that all preferred colours were selected in the context of p4m tiling. Moreover, 58.1% of the total abstract colours preferred were matched with coloured p4m patterns preferred, which means that the sampled Young Omani designers prefer their preferred colours and p4m symmetry patterns to match. This interesting result suggests a strong relationship and impact of colour preference on p4m grid design selection. These findings align with previous research studies, indicating consistency between personal and product colours, which suggests extending the analysis of these relationships to a broader range of design products [33, 34].

Four of the eight emotional scales, namely clean, fresh (evaluative factors), active and relaxing (activity factors), exhibited high-intensity emotional responses, reflecting a strong positive association between these emotions and preferred colours. On the other hand, heavy, soft (potency factors), classical and warm (activity factors) emotional scales represented even and low-level rating responses. This means reactions to these emotions were less deceitful than those to clean, active, fresh, soft, and relaxing emotions. Moreover, the emotional factors classes used in this study, evaluative emotional factor, are the most critical and sensitive emotional factors, followed by activity factors, which affect colour preference and consequently colour p4m configuration preference. On the other hand, the potency factors, including heavy and soft, play a lesser role in determining the preferred evoked colours.

Moreover, the relaxing scale (Activity factor) showed that green is the most restful colour, followed by Blue, then Yellow, Magenta, and Red was the least relaxing. Therefore, green is at the top of the three scales: clean, fresh, and relaxing, which agrees with previous research indicating that green is perceived as clean, peaceful, fresh, and relaxing [1, 3, 42]. However, Red was the least effective on the same three scales. Therefore, these findings suggest that cold colours have a calming effect on emotions. In the activity factors, four emotions are explored, namely classical, warm, active, and relaxing. Yellow was found to dominate two emotional scales, namely classical and warm. It is interesting to find yellow a new colour recognised as

a classical one, rather than natural colours, which were long known in civilisations as traditional classics, such as magenta and blue [43]. Noteworthy is that yellow was found in previous research works, as well as in warmth-effective works [3].

The Classical emotional findings show a significant similarity between the two emotional scales. Furthermore, activity factors, represented by classical and warm, are associated positively with colour temperature and vice versa; the colder the colour, the lower the classical or warm colour is. On the active emotional scale, as an activity factor, Magenta was ranked as the most active, followed by Green, Yellow, Blue, and then Red. Although, the potency emotional findings suggest that red was perceived as the heaviest colour, which aligns with previous research work [44, 45]. However, green showed as the lightest colour across the colours examined, which is in line with previous research findings that green's apparent weight is lighter than that of other hues [45, 46]. However, for the soft scale, blue was the most colour recognised, agreeing with previous research studies that associate blue with calmness and peace [3], followed by green, magenta, red, and yellow, which is the hardest colour.

Therefore, green is the most emotionally evoking colour across all colours, being the highest in three emotional scales: clean, fresh, and relaxing. Yellow follows green as a leading colour to two emotions, namely classical and warm. Magenta, red, and blue were perceived as the highest effective on active, heavy, and soft emotional scales, respectively. Furthermore, these findings align with studies that have linked positive emotions to preferred colours [14, 20].

The non-statistical significance difference detected for emotional ratings across preferred colours for all colours ($p > .05$ in each colour) except "Relaxing". This means that the relaxing emotional scale was statistically significant when reacting to the explored colours. The statistical findings indicate that the perception of relaxation varies widely depending on the colour students in the sampled design group chose. Additionally, the findings of the z scores for pairwise comparisons showed statistically significant differences in mean ranks, indicating how the sampled cohort rated the "Relaxing" emotion in relation to their preferred colour. Consequently, based on the z scores' significance and directions, the order ranking from the highest to the least evoking relaxing emotion could be inferred from the following findings: Blue > Green > Yellow > Magenta > Red. The analyses of weighted means calculated for Green and Blue colors emotional impressions; suggests that -within the context p4m configuration- preference is not purely

affected by the relaxing emotional impact of color but also by a combination of factors from potency factors reperesnetd by how heavy and soft a colour is sensed and from activity group reperesnetd by to what extent it is classical and warm. This multidimensional combination and balanced emotional profile, rather than a single emotional peak, can illustrate the Blue's ground of being of a primary preference, despite the green being detected as the highest rank on the relaxing scale.

These findings provide strong evidence of colour-emotion associations in the light of colour relaxation and preference scales. These findings align with previous findings in colour-emotion research, indicating that hues like green [1, 3, 42] and red [3, 42] can evoke the most calming and intense emotional responses, respectively, depending on design context and personal associations. These findings suggest that all colour emotions, except relaxing emotions, are perceived consistently across all colours examined. Furthermore, Blue and green colours have the highest emotional strength on these emotional scales.

CONCLUSIONS

This study is a pilot exploratory investigation focusing on female design students to obtain preliminary insights into colour–pattern (within the p4m framework) perception within a homogeneous emerging consumer group, providing a foundational baseline for future large-scale research. An online survey relevant to the research questions and objectives was administered to collect primary data from undergraduate design majors. The collected data were statistically analysed using both descriptive and inferential methods to gain a comprehensive understanding of the research area. The sampled cross-section of young Omani designers' preference in the context of p4m tiling, which was liked by subjects in both black-and-white modes, was found to depend on the colour used. As an exploratory pilot study, the findings provide preliminary indications of how female design students perceive colour and p4m-based stimuli. Blue was seen, among the current study sample, to be the most preferred colour within the p4m framework preference, followed by yellow and green, then red. Magenta was the least preferred colour across the examined coloured p4m grid design. For the contextless colour preference, the sampled design students were strongly drawn to blue, as around half selected it as their favourite from the five colours presented (including green, yellow, red, and magenta). Abstract colours were ranked from high to low: blue,

then magenta, then yellow, and finally red. Again, the magenta showed the least preference level across the sampled student demographic.

Furthermore, the role of the sampled design students' personal abstract colour choices within the p4m framework preference was investigated. The relationship between preference for colour and coloured p4m symmetry preference was explored employing ordinal ranking and colour consistency rates. In terms of ranking, both were ranked similarly. Additionally, the consistency rates of all colours were found to be equal to or higher than 50% CRR, which is significantly higher than the CRR threshold of 20%. These findings suggest a consistent association between a preference for abstract colours and p4m grids in design, indicating the significant role of colour in p4m structural design in the current study sample. Consumers who preferred a colour tended to choose a p4m-symmetric design in that colour, demonstrating moderate to high consistency.

These findings suggest that colour is a dominant factor within the p4m pattern design framework. However, the p4m structure design has a lower influence than colour, and its preference depends on abstract colour preferences. Therefore, the correlation between the sampled student cohort's choice of abstract colours and preferred colour in the context of p4m tiling is strong.

The emotional impact of colours was explored to highlight the cohort's tendencies towards colour and p4m configuration preferences. The extent to which a preferred colour is selected evokes emotions associated with heaviness, classicism, cleanliness, activity, freshness, softness, relaxation, and warmth. The colours examined were found to be perceived differently in the emotional dimensions employed. Green was found to be the cleanest, freshest, and relaxing; however, red is the weakest in these emotional dimensions. Yellow is perceived as the most classical and warm, whereas green is perceived as the least warm for these emotions. Magenta, red, and blue are the most evocative colours for active, heavy, and soft. These findings agreed with previous research works investigating the emotional impacts of colour.

Regarding "blue", the most preferred colour, as an abstract and within the p4m framework, the controlling emotions signifying this colour are being of the highest level of softness, high impression of being clean, fresh and relaxing (occupied the second position on these emotional scales across colours examined), good perception as a classical and heavy colour (secured the third/medium place on these dimensions), finally low impression of being warm and active (in the fourth rank across the colours explored on these

emotional dimensions). Adopting these findings, the preferred colours could be visually described as extremely soft, powerfully associated with clean, fresh, and relaxing; moderately expressed as classical and heavy, yet mildly emotional due to their warmth and activity. Noteworthy is that, however, all emotions were able to differentiate colours tested, the relaxing emotional scale showed significant discrimination between the groups of colours. These findings can provide insights for textile and fashion designers regarding colour-emotion association while creating pattern designs.

These findings are consistent with affective congruence theories, and research suggests that colour has affective power that can enhance the design of a product's effectiveness. Besides, these findings suggest a dominating role of colour as a driving force in the in the context of p4m tiling, rather than design configuration. Therefore, it highlights implications for colour applications, considering the emerging consumer's colour preference in the textile and fashion design field, an area that extensively employs pattern designs. Additionally, these findings can provide insights for designers in contexts where they aim to evoke feelings of relaxation, calmness, or restfulness, though further justification might be required. Moreover, these findings indicate an association between colour preference and emotional scales, supporting the emotional design-informed aesthetic preferences of visual design. For design education, colour design would be equipped with knowledge grounded in geometrical patterns and colour interactions, which can be applied across various fields of art and design.

RESEARCH LIMITATIONS

This study involved female undergraduate design students, who represent the population from which the sample was drawn; however, future studies may consider gender differences in broader demographic populations. Moreover, the current research focused on a selected range of principal hues as the primary independent variable, whereas future research will employ a broader range of hues with varying values and chroma levels. This study is limited to a single symmetry group, i.e., p4m, which represents a highly ordered, preferred, and stable structure in textile design that allows controlled exploration of colour-pattern interaction and enables focused analysis. This choice of a single pattern, p4m, inherently limits the study's scope to periodic, geometric designs, which may exhibit different interactions in a similar context. Future research should examine the persistence of current findings when extending variance to pattern-

configuration types and to enhance the generalizability of the findings. While it is acknowledged that fixing colour positions and sequences may introduce residual position-related bias, such as primacy or recency effects, the use of a universally recognized logical sequence (the natural spectrum) reduces the risk of these biases being arbitrary, as it provided a predictable and fluent navigation path for the participant's eye, thereby maintaining the internal validity of the colour selection process. Future studies will aim to achieve a balanced distribution of preference and emotional responses across all colors tested, including green, to re-examine the ranking of the colors tested in the current study. Besides, the emotional responses linked to the tested colors in this study might vary in textile applications (specifically, the relaxing emotion), which often use light, muted colors.

Author Contributions

Conceptualization – Sanad R and Hanafy I; methodology – Sanad R and Hanafy I; formal analysis – Sanad R and Hanafy I; investigation – Hanafy I; writing-original draft preparation – Sanad R; writing-review and editing – Sanad R and Hanafy I; visualisation – Sanad R. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Hazards

Not Applicable.

Human Research Subjects

This research was conducted in accordance with relevant guidelines and regulations for surveys involving humans, and informed consent was obtained from all human research subjects.

Ethical Approval

Ethical approval was obtained on April 8th, 25, to conduct the current research from the Postgraduate Studies & Scientific Research Committee at ZCW College, Sultanate of Oman (Approval No. 082/2024-2025). The research adhered to ZCW College Ethical Policy, which aligns with internationally recognised principles for research involving human participants as outlined in the Declaration of Helsinki (2013 revision).

Informed Consent

All participants are university students who were introduced to the electronic questionnaire in their college and informed about the strict measures taken to maintain their anonymity, the confidentiality of their identities, and the confidentiality of the data provided. Introductively, they were provided with information about the current study scope and purposes.

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Not Applicable.

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