Visual impact of colours in various painting media: oil paint, watercolour, pastel, and digital art

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This study explores how different painting media – oil paint, watercolour, pastel and digital art – affect visual perception through colour manipulation. A total of 160 painting images, representing each medium, were used in a psychophysical experiment involving 10 colour emotion scales. These scales measured attributes including warm/cool, heavy/light, modern/classical, clean/dirty, passive/active, hard/soft, relaxing/tense, fresh/stale, feminine/masculine and like/dislike. Thirty observers with normal colour vision participated in the study. Principal component analysis revealed that among the 10 colour emotion scales, only the "like/dislike" scale showed a wide distribution of data points in the principal component plots. This dispersion indicates a significant effect of painting category on colour preference within the images. The experimental results also indicated that different painting categories were associated with distinct primary colour emotions that influenced liking. These findings highlight how painting medium/style shape the visual impact of colours, particularly in terms of preference.

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Introduction

Colour is a fundamental element in painting, playing a crucial role across various painting media. Its importance transcends mere aesthetics, influencing the emotional, psychological and visual impact of an artwork. Each painting medium seems to interact with colour in unique ways, offering distinct possibilities and limitations that artists can exploit to express their vision.

Oil painting

Oil paint is renowned for its rich, textured application and versatility. The use of oil-based pigments suspended in a binder such as linseed oil allows for slow drying times, which enables artists to blend colours seamlessly, achieve smooth transitions and create various textures and translucency. The oil medium's ability to create luminous colours is unparalleled. By applying layers of translucent glazes and directly mix colours on canvas, artists can achieve a depth and richness that gives the painting a glowing, lifelike quality. The oil medium allows light to penetrate through the layers, reflect off the surface below, and create a vibrant, three-dimensional effect [1]. For instance, V. van Gogh's thick, expressive brushstrokes with oil paint create dynamic textures and enhance the emotional intensity of his works [2]. "The Night Watch" by Rembrandt van Rijn showcases his mastery of light and shadow and his ability to create depth and texture through meticulous layering and blending. The rich, dark tones and the luminous quality of the figures exemplify the strengths of oil paint.

Watercolour painting

In contrast to oil painting, watercolour employs pigments dissolved in water and bound with gum arabic. Watercolour's transparency and fluidity lend it a distinctive luminous quality, with colours appearing more delicate and ethereal compared to the denser hues of oil paint. Artists like J. M. W. Turner often use the white of the paper to create highlights and luminous areas, making the interplay of light and shadow more pronounced and ethereal [3]. The fluid nature of watercolour enables a level of spontaneity and unpredictability in the artwork. Techniques like wet-on-wet and wet-on-dry give watercolour artists the flexibility to create both loose washes and fine details. For instance, J. S. Sargent's watercolours are renowned for their vibrant colours and loose, spontaneous brushwork, exemplifying his ability to use the transparency and lightness of watercolour to create vivid, dynamic compositions that capture the essence of the subject matter with immediacy and freshness [4].

Pastel painting

Pastels are created from powdered pigment bound with a minimal amount of gum or resin, resulting in a dry medium that is usually applied directly onto a coloured paper. Pastels come in two main types: soft pastels, which are powdery and easily blendable, and oil pastels, which have a creamy consistency and can be applied thickly like oil paint. Both types offer intense, pure colours and allow for a direct, tactile approach to colour application. Pastels are prized for their immediacy and ability to create bold, expressive marks, making them ideal for capturing vivid landscapes, portraits, and still lives. The texture of the paper and the layering of pastel strokes contribute to a tactile richness and depth, enhancing the visual impact of the artwork. Artists such as E. Degas and M. Cassatt have utilised pastels to convey spontaneity and emotion, capturing fleeting moments and delicate nuances with vibrant colour.

Studies of colour emotion

"Colour emotion" is a term used in recent studies [5-17] to explore the relationship between colour and its affective quality, whether of the colour itself or the environment/product. This term was first introduced by Sato [5-6] and later adopted by Ou [7-9, 13-14, 17], both key researchers in this field. Previously, this research area was referred to by various names, such as colour meaning [18-22], colour image [23-24] and expectations [25-26]. This inconsistency led to confusion [27], as the studies often

focused on colour-word associations (e.g. warm/cool or heavy/light) rather than colour-emotion associations (e.g. pleasure or arousal). To ensure consistent terminology, this article uses the term "colour emotion" to describe this research area.

Two main methods measure colour emotion responses: semantic differential and categorical judgement. Psychophysiological methods have also gathered biofeedback data, such as skin conductance, electroencephalogram, corrugator electromyography and heart rate. Principal component analysis and multiple regression methods have been employed to identify underlying factors and develop mathematical models of colour emotion responses.

Key findings have included the identification of three common factors: hue-related (e.g. warm/cool), lightness-related (e.g. soft/hard), and chroma-related (e.g. passive/active). The colour emotion response to a pair of colours can be determined by averaging the individual colour values, except for the like/dislike scale [8, 14, 17, 28]. Although some studies suggest the colour area ratio affects this response, these effects are generally insignificant [15-16]. This additivity relationship has been found to apply well to three-colour combinations [29] and multi-colour images [30], showing high agreement between observed and predicted values. In addition, colour emotion responses (e.g. warm/cool, heavy/light and passive/active) have been found to be consistent across different regions in the world [12-13, 17].

Aims of study

The selection of painting medium and the application of colour in each medium seem to evoke distinct visual impacts, influencing atmospheric effects and emotional responses. Oil painting is renowned for its richness, depth, and versatility, while watercolour excels in transparency, luminosity, and creating atmospheric effects. Pastel stands out for its intensity, softness, and textured surface. However, there is a lack of empirical study on how these differences in visual impact manifest across different painting media. Further exploration using psychophysical methods would be invaluable to clarify how the painting medium and colour interact to create specific visual impacts in paintings. This could help provide deeper insights into how artists and viewers perceive and respond to colours based on the medium used, paving the way for enhanced techniques and creative possibilities in visual art.

Thus, this study aims to compare the visual impacts of colour on paintings created with various media. The visual impacts of colour were defined using colour emotion scales. Existing findings of research into colour emotion [5-17] served as theoretical basis for data analysis in this study.

Methods

Original paintings

To achieve the aims of this study, a psychophysical experiment was conducted using paintings as stimuli. The paintings were created by the first author of the study using 4 different media: oil paint on canvas, watercolour on paper, soft pastel on black paper, and digital art created with the Procreate app on iPad Pro. Each medium was used to create two distinct subjects: one featuring a t-shirt and the other a vase. These subjects were chosen because of their simple contours, facilitating colour manipulation for generating test images in the experiment. This approach resulted in a total of 8 original paintings (i.e. 4 media × 2 subjects), as shown in Figures 1a-h. Each painting had an original size close to A4. It is noteworthy that digital painting has increasingly become a widely used tool in recent years due to its

meticulous control over colour application and freedom for experimentation, without the constraints of traditional media. Therefore, digital painting was also included as a medium in this study.

(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 1: The 8 original paintings created by the first author: (a) oil on canvas - shirt, (b) oil on canvas - vase, (c) watercolour on paper - shirt, (d) watercolour on paper - vase, (e) soft pastel on black paper - shirt, (f) soft pastel on black paper - vase, (g) digital painting with Procreate - shirt and (h) digital painting with Procreate – vase.

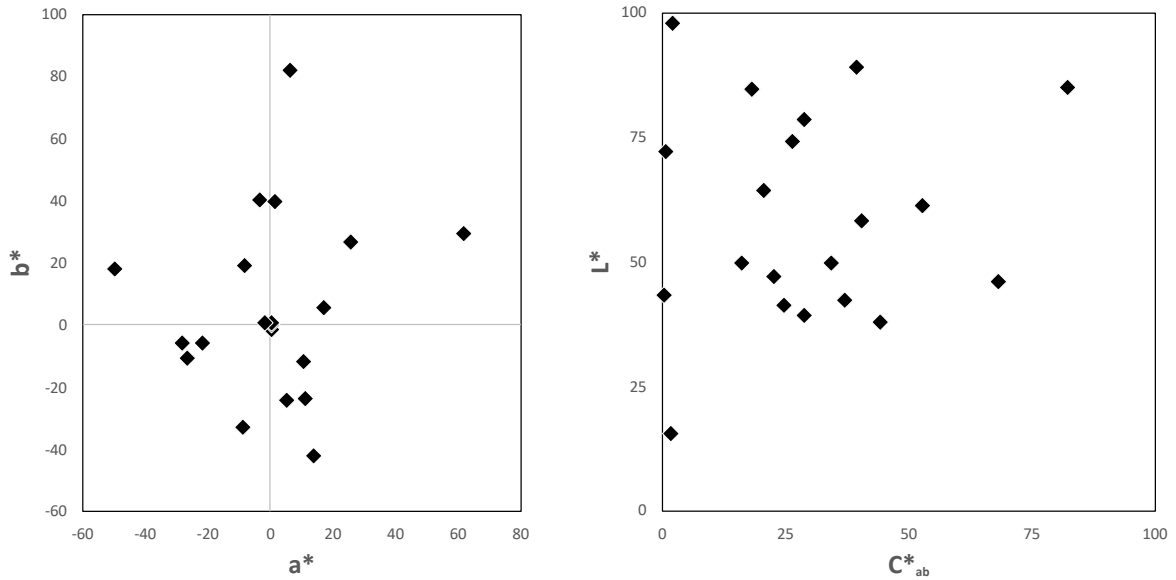
Colour stimuli

To investigate how colours affect observers' responses to the paintings, test images were created using the 8 original paintings previously described. Each image was manipulated to change the colour of the main part of the painting using Matlab software. Ou's earlier colour emotion study [7] utilised 20 colours selected from the NCS Colour Atlas, covering a wide range of hue, lightness, and chroma in CIELAB colour space [31]. To ensure comparability with previous findings, these same 20 colours were used in the present study.

Table 1 provides a summary of CIELAB values for these 20 colour samples. Figures 2 shows the distribution of the 20 colours in CIELAB. By applying each of the 20 colours to the main part of each of the 8 original paintings, a total of 160 test images were generated for use in the experiment (8 original paintings × 20 colours). Figures 3 to 6 show the 160 test images used in this study for oil painting, watercolour, pastel and digital painting, respectively. During the experiment, these test images were shown one at a time in random order on a computer display. The observer's task was to rate each test image using colour emotion scales, as described in the following sub-section.

Sample	L*	a*	b*	C^*_{ab}	h_{ab}
1	45.9	61.7	29.1	68.2	25
2	84.8	6.3	82.0	82.3	86
3	61.4	-49.7	17.8	52.8	160
4	49.6	-8.9	-33.2	34.4	255
5	38.0	13.8	-42.0	44.2	288
6	42.2	25.9	26.5	37.0	46
7	58.3	-3.2	40.3	40.4	94
8	39.3	-28.2	-5.8	28.8	192
9	41.4	5.0	-24.3	24.8	282
10	84.7	17.1	5.6	18.0	18
11	89.0	1.6	39.4	39.4	88
12	78.4	-26.7	-10.9	28.8	202
13	74.0	11.3	-23.7	26.3	296
14	64.2	-8.2	19.0	20.7	113
15	47.1	-22.0	-5.7	22.7	195
16	49.8	10.8	-11.9	16.1	312
17	15.7	0.3	-1.5	1.6	282
18	43.2	0.3	0.2	0.4	37
19	72.1	0.4	0.6	0.7	58
20	97.8	-2.1	0.4	2.1	168

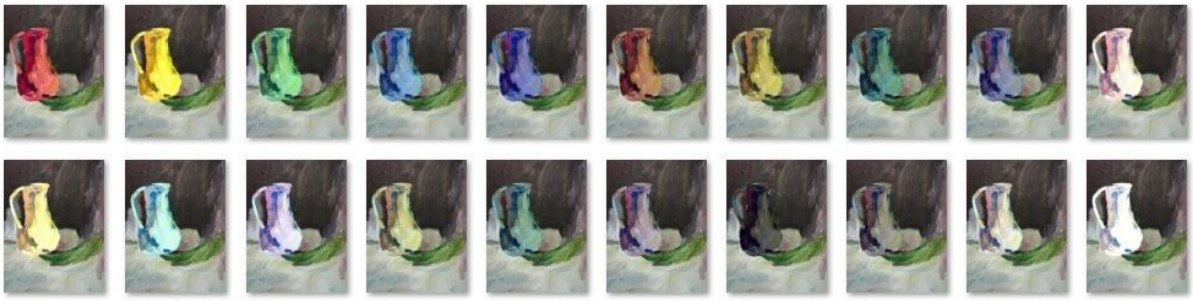
Table 1: CIELAB specifications of the 20 colour samples used in this study.



(a) (b)

Figure 2: Distribution of the 20 colour samples in CIELAB space: (a) the a vs. b* plot and (b) the L* vs. C^*_{ab} plot.*

(a)



(b)

Figure 3: Test images vase of oil paintings manipulated into the 20 colours for the two subjects: (a) shirt and (b).

(a)

(b)

Figure 4: Test images of watercolour paintings manipulated into the 20 colours for the two subjects: (a) shirt and (b) vase.

Figure 5: Test images of pastel paintings manipulated into the 20 colours for the two subjects: (a) shirt and (b) vase.

Figure 6: Test images of digital paintings manipulated into the 20 colours for the two subjects: (a) shirt and (b) vase.

Colour emotion scales

Ou's earlier colour emotion study [7] employed 10 bipolar semantic scales, referred to as "colour emotion scales" in this article. These scales included: warm/cool, heavy/light, modern/classical, clean/dirty, passive/active, hard/soft, relaxing/tense, fresh/stale, feminine/masculine and like/dislike. The 10 scales were classified into three colour emotion factors: "colour activity", "colour weight" and "colour heat" [7]. These scales were the most frequently used in early research on colour emotion and were also found to be suitable for defining the visual impacts of colour in paintings. For consistency and to compare the present experimental results with previous findings, the present study also used these 10 scales in the psychophysical experiment. Each scale had 6 levels of intensity. For example, the warm/cool scale included "very warm", "warm", "a little warm", "a little cool", "cool" and "very cool". The observer responses for each of the 10 colour emotion scales were converted into z-score related scale values using the categorical judgement methods introduced by Torgerson [32].

Display

The experiment was conducted in a darkened room where an Eizo ColorEdge CG241W liquid crystal display, calibrated with an X-Rite i1, was utilised to present the test images. The display featured a peak white with a correlated colour temperature of 6500K and a luminance of 73.1 cd/m^2. The relatively low display luminance was chosen to avoid eye fatigue of the observers in this study, who sat in a room where the display served as the sole light source. The 160 test images were presented on the display one at a time in random order during the experiment. Between each test image was a full screen of neutral grey lasting for 2 seconds to avoid any after-image effect.

Observers

Thirty observers, consisting of 15 males and 15 females aged between 20 and 40 years, participated in the experiment. All observers passed Ishihara's test for colour deficiency. None of them had a professional background in art or design to avoid any influence of professional training on their responses in this study.

During the experiment, each observer sat approximately 50 cm away from the experimental display. They rated the 160 test images using 10 colour emotion scales, employing the categorical judgment method [32] for data collection. To assess repeatability (i.e. the intra-observer variability), each observer completed the experiment twice.

Results

Data reliability

Two measures were used to examine the reliability of the experimental data: inter-observer variability and intra-observer variability. The inter-observer variability, meaning how well the observers agree with each other on the same test colour sample, was determined by the Root Mean Square (RMS). For colour *j*, the inter-observer variability can be quantified by Equation 1:

$$RMS_j = \sqrt{\frac{\sum_{i=1}^{m}(x_i - \bar{x})^2}{m}} \quad (1)$$

where x_i represents the response of observer i for the test colour sample; $\bar{x}$ represents the average of responses by all observers for the same colour; m is the number of observers. The lower the RMS value is, the more closely the observers agree with each other on colour j.

The intra-observer variability, meaning how repeatable the observer's response was to the same test colour sample, was also determined by RMS. For observer i, the intra-observer variability can be quantified by Equation 2:

$$RMS_i = \sqrt{\frac{\sum_{j=1}^{n}(x_j - y_j)^2}{n}} \quad (2)$$

where x_j represents the response to colour j given for the first time; y_j represents the response to the same colour given for the second time; n is the number of colours. The lower the RMS value is, the more repeatable the observer's response.

Table 2 shows the mean values of inter- and intra-observer variability for the 10 colour emotion scales, indicating the lowest inter-observer variability for relaxing/tense (1.55) and hard/soft (1.59), suggesting that the two scales, relaxing/tense and hard/soft, had the most consistent observer responses. In terms of intra-observer variability, on the other hand, heavy/light (1.43), feminine/masculine (1.47) and fresh/stale (1.47) are the lowest, indicating that observers' responses were most repeatable for these three scales. The table shows the highest values of inter- and intra-observer variability both for like/dislike (1.89 and 1.76 respectively), indicating that the observer responses were least consistent and least repeatable for the like/dislike scale in this study.

	Inter-observer variability	**Intra-observer variability**
warm/cool	1.66	1.55
heavy/light	1.73	1.43
modern/classical	1.65	1.61
clean/dirty	1.72	1.48
passive/active	1.85	1.65
hard/soft	1.59	1.67
relaxing/tense	1.55	1.49
fresh/stale	1.73	1.47
feminine/masculine	1.81	1.47
like/dislike	1.89	1.76

Table 2: Inter- and intra-observer variability for the 10 colour emotion scales, in terms of RMS values.

Principal component analysis

To investigate the interrelationship between observers' responses on the 10 colour emotion scales across 8 painting categories (oil painting - shirt, oil painting - vase, watercolour - shirt, watercolour - vase, pastel - shirt, pastel - vase, digital - shirt, and digital - vase), a principal component analysis (PCA)

was conducted using SPSS statistical software. The input data included 80 variables, derived from 8 painting categories and 10 colour emotion scales. Each variable consisted of categorical judgment scale values rated for images manipulated into the 20 test colours.

Figures 7a-b show principal component plots based on 3 principal components: "modernity", "relaxation" and "warmth", as extracted from the PCA. These 3 orthogonal components accounted for 87.7% of the total variance, suggesting good coverage of data variation in the 8 painting categories and the 10 colour emotion scales. The 3 principal components – "modernity", "relaxation" and "warmth" – correspond to the common structure of colour emotion factors in early research of colour emotion: chroma-related (e.g. passive/active), lightness-related (e.g. soft/hard) and hue-related (e.g. warm/cool) [5-17]. Note that there was a main difference between the early research on colour emotion and the present study: the inclusion of painting categories in the test images. The similar structures of colour emotion in these studies, including the present research, suggest that observers shared common responses to colour perception regardless of image content.

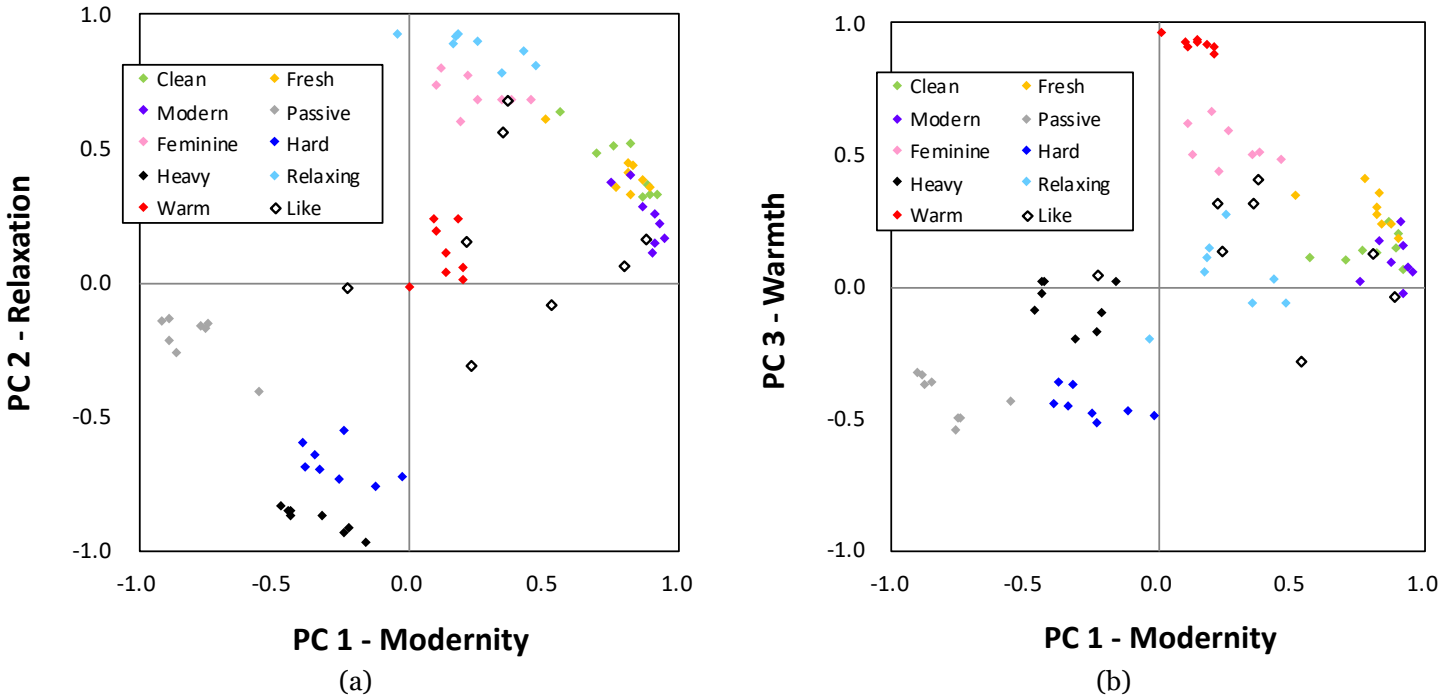


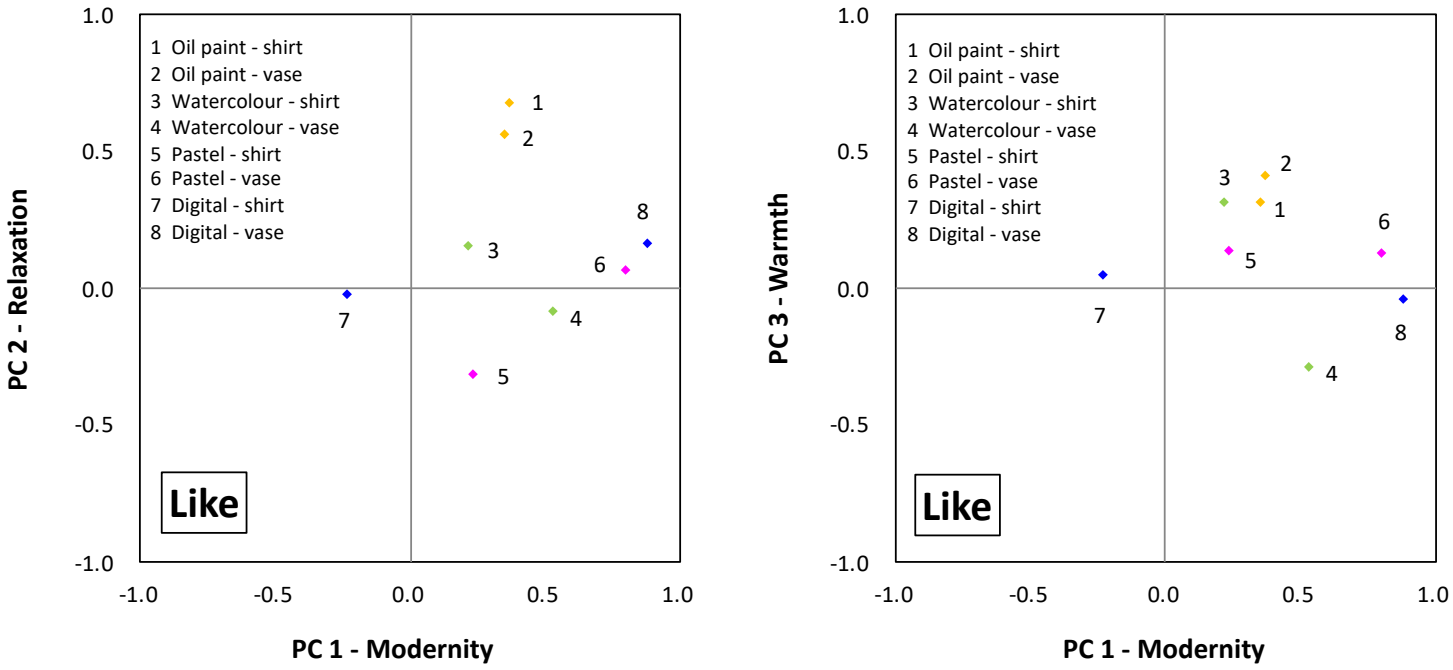
Figure 7: Principal component plots: (a) PC 1 (modernity) vs. PC 2 (relaxation) and (b) PC 1 (modernity) vs. PC 3 (warmth).

In each graph, dots of the same label colour represent the observer responses of the same colour emotion scale to the 8 painting categories (i.e., 4 painting media by 2 subjects). For instance, the 8 red dots represent the observer responses for the 8 painting categories in terms of warm/cool. It is noteworthy that the dots of the same label colour are located close to each other for all colour emotion scales except for the like/dislike scale. For instance, the 8 red dots (labelled "warm") are all located prominently along the "PC 3 - Warmth" axis, and the 8 purpose dots (labelled "modern") are all located prominently along the "PC 1 - Modernity" axis. These results indicate that observer responses (except for like/dislike) to each test colour were consistent across the 8 painting categories. In other words, the colour emotion response (except for like/dislike) was independent of the painting category in this study.

The like/dislike scale is the only scale that shows a wide spread of white dots in both graphs, suggesting a strong impact of painting category on colour emotion for the like/dislike scale. Figures 8a-b show the distribution of the like/dislike dots in the principal component plots. In these graphs, dots

of the same label colour represent the same painting medium. For instance, the two yellow dots (representing oil paintings) are both located high along the "PC 2 - Relaxation" axis, suggesting the observers' liking for the two oil paintings were affected by the "relaxing" feeling. Most of the dots are located on the positive side of the "PC 1 - Modernity" axis, with the only exception being dot 7. This indicates that the observers tended to like paintings that show feelings of modern, clean and fresh.

Interestingly, the dots of the same painting medium are not necessarily located close to each other, complicating the explanation of like/dislike responses for the painting medium. For instance, dots 7 and 8, both representing the like/dislike responses for the digital paintings, are located far apart. Note that the two original paintings corresponding to dots 7 and 8, as shown in Figures 1 (g) and (h), demonstrate different painting styles, suggesting that the like/dislike response was influenced not only by the painting medium but also by the painting style.



(a) (b)

Figure 8: Principal component plots for the like/dislike scale: (a) PC 1 (modernity) vs. PC 2 (relaxation) and (b) PC 1 (modernity) vs. PC 3 (warmth). Coloured dots represent the like/dislike responses to the 8 painting images.

The like/dislike responses

The distinction between the like/dislike response and the responses of the other colour emotion scales, as shown in Figures 7a-b, is detailed in Table 3. The three scales "modern/classical", "relaxing/tense" and "warm/cool" are most closely correlated with the three principal components "modernity", "relaxation" and "warmth" respectively, making them good representatives of all colour emotion scales studied, except for like/dislike. As shown in the table, the correlation coefficient values between the 8 painting categories are very high for each of these three scales, indicating consistent observer responses across the 8 painting categories. In contrast, the correlation coefficients for the like/dislike scale vary widely, including a negative value of -0.27 for the correlation between the oil-paint vase and the digital shirt.

modern/classical	1	2	3	4	5	6	7	8
1. Oil paint - shirt		0.83	0.90	0.96	0.82	0.89	0.91	0.94
2. Oil paint - vase	0.83		0.82	0.82	0.80	0.79	0.89	0.78
3. Watercolour - shirt	0.90	0.82		0.91	0.88	0.90	0.92	0.90
4. Watercolour - vase	0.96	0.82	0.91		0.85	0.94	0.89	0.97
5. Pastel - shirt	0.82	0.80	0.88	0.85		0.88	0.88	0.85
6. Pastel - vase	0.89	0.79	0.90	0.94	0.88		0.91	0.94
7. Digital - shirt	0.91	0.89	0.92	0.89	0.88	0.91		0.90
8. Digital - vase	0.94	0.78	0.90	0.97	0.85	0.94	0.90	

relaxing/tense	1	2	3	4	5	6	7	8
1. Oil paint - shirt		0.92	0.89	0.83	0.91	0.91	0.77	0.86
2. Oil paint - vase	0.92		0.91	0.84	0.93	0.89	0.87	0.86
3. Watercolour - shirt	0.89	0.91		0.85	0.88	0.85	0.82	0.88
4. Watercolour - vase	0.83	0.84	0.85		0.79	0.88	0.78	0.89
5. Pastel - shirt	0.91	0.93	0.88	0.79		0.91	0.84	0.85
6. Pastel - vase	0.91	0.89	0.85	0.88	0.91		0.79	0.94
7. Digital - shirt	0.77	0.87	0.82	0.78	0.84	0.79		0.75
8. Digital - vase	0.86	0.86	0.88	0.89	0.85	0.94	0.75	

warm/cool	1	2	3	4	5	6	7	8
1. Oil paint - shirt		0.94	0.92	0.91	0.89	0.94	0.91	0.92
2. Oil paint - vase	0.94		0.93	0.86	0.88	0.93	0.92	0.90
3. Watercolour - shirt	0.92	0.93		0.90	0.84	0.89	0.86	0.93
4. Watercolour - vase	0.91	0.86	0.90		0.86	0.90	0.87	0.91
5. Pastel - shirt	0.89	0.88	0.84	0.86		0.92	0.87	0.90
6. Pastel - vase	0.94	0.93	0.89	0.90	0.92		0.92	0.95
7. Digital - shirt	0.91	0.92	0.86	0.87	0.87	0.92		0.89
8. Digital - vase	0.92	0.90	0.93	0.91	0.90	0.95	0.89	

like/dislike	1	2	3	4	5	6	7	8
1. Oil paint - shirt		0.61	0.46	0.22	0.12	0.53	0.16	0.55
2. Oil paint - vase	0.61		0.65	0.20	0.00	0.31	-0.27	0.36
3. Watercolour - shirt	0.46	0.65		0.52	0.37	0.32	0.17	0.36
4. Watercolour - vase	0.22	0.20	0.52		0.53	0.48	0.28	0.72
5. Pastel - shirt	0.12	0.00	0.37	0.53		0.49	0.63	0.40
6. Pastel - vase	0.53	0.31	0.32	0.48	0.49		0.24	0.83
7. Digital - shirt	0.16	-0.27	0.17	0.28	0.63	0.24		0.09
8. Digital - vase	0.55	0.36	0.36	0.72	0.40	0.83	0.09	

Table 3: Pearson correlation between the 8 painting categories for scales: modern/classical, relaxing/tense, warm/cool and like/dislike.

Figures 9a-d demonstrate the variation in like/dislike correlation between different painting categories. Figures 9a-b show extremely low correlations: a coefficient of 0.00 between the oil-paint vase and the pastel shirt, and a coefficient of -0.27 between the oil-paint vase and the digital shirt. In contrast, Figures 9c-d show high correlations: a coefficient of 0.72 between the digital vase and the

watercolour vase, and a coefficient of 0.83 between the digital vase and the pastel vase. These graphs provide clear examples of the significant variation in like/dislike correlation between different painting categories.

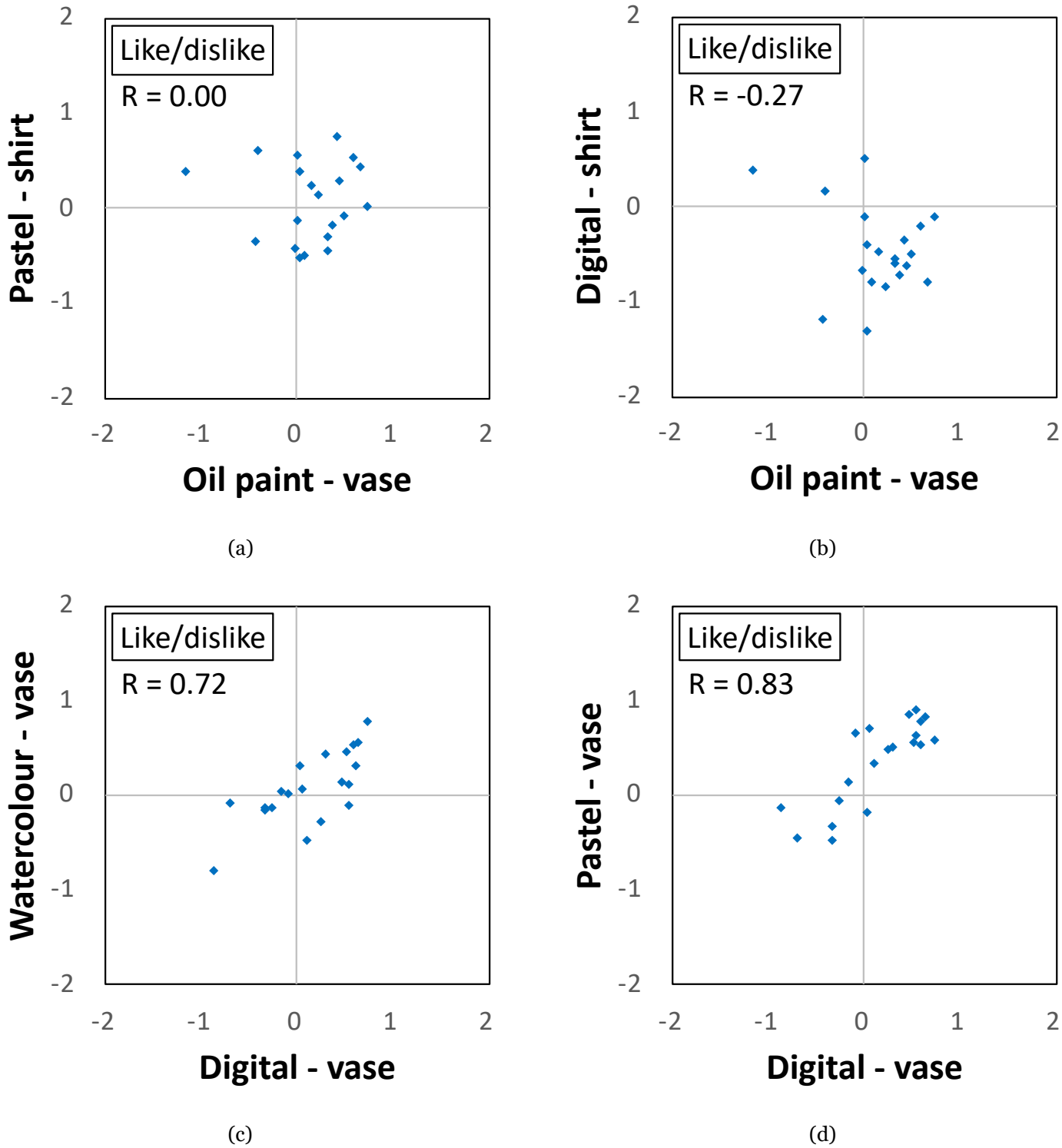


Figure 9: Comparisons of the like/dislike responses between different painting categories: (a) oil-paint vase vs. pastel shirt, (b) oil-paint vase vs. digital shirt, (c) digital vase vs. watercolour vase and (d) digital vase vs. pastel vase.

Figure 10 shows the 20 colours of the painting images ranked by like/dislike responses across the 8 painting categories. There are common trends in these rankings. For instance, greyish colours and some dark colours tend to be disliked regardless of the painting category. However, there are also notable differences. For example, black is extremely liked in some categories (e.g. the digital shirt and the watercolour vase) but extremely disliked in others (e.g. the oil-paint vase and the watercolour shirt). These differences in rank orders support the wide spread of like/dislike dots shown in Figures 7 (a)-(b) and the significant variation in correlation coefficients between the 8 painting categories for the like/dislike scale shown in Table 3.

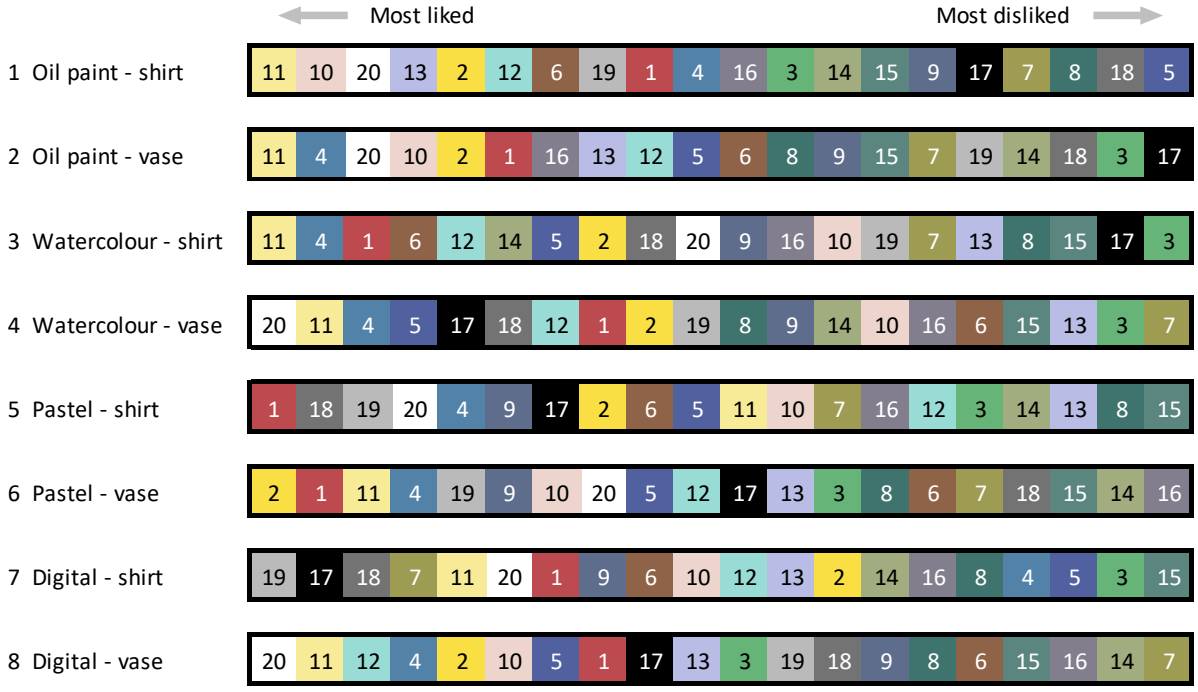


Figure 10: The 20 colour samples ranked in order of liking for the 8 painting categories.

Table 4 displays correlation coefficients between like/dislike and other colour emotion scales for the 8 painting categories.

	warm/ cool	heavy/ light	modern/ classical	clean/ dirty	passive/ Active	hard/ soft	relaxing/ tense	fresh/ stale	feminine/ masculine
1. Oil paint - shirt	0.60	-0.85	0.33	0.71	-0.65	-0.66	0.86	0.70	0.82
2. Oil paint - vase	0.50	-0.68	0.47	0.79	-0.77	-0.77	0.72	0.75	0.65
3. Watercolour - shirt	0.43	-0.26	0.30	0.46	-0.42	-0.31	0.15	0.32	0.30
4. Watercolour - vase	-0.10	-0.23	0.35	0.49	-0.38	-0.02	0.19	0.40	0.02
5. Pastel - shirt	0.28	0.19	0.19	0.28	-0.38	0.19	-0.24	0.26	-0.14
6. Pastel - vase	0.30	-0.45	0.81	0.81	-0.80	-0.37	0.40	0.72	0.48
7. Digital - shirt	0.11	-0.02	-0.21	0.16	0.01	0.16	0.06	-0.21	0.01
8. Digital - vase	0.06	-0.58	0.86	0.87	-0.75	-0.39	0.57	0.79	0.36
Mean	0.27	-0.36	0.39	0.57	-0.52	-0.27	0.34	0.47	0.31

Table 4: Correlation between like/dislike and the other colour emotion scales for the 8 painting categories.

The results suggest that different painting categories were associated with distinct key colour emotions influencing liking. For instance, liking for "1. Oil paint - shirt" is highly correlated with feelings such as "relaxing", "light" and "feminine", while liking for "8. Digital - vase" is closely correlated with feelings of "modern", "clean" and "active". These findings align with the positioning of like/dislike dots in Figures 8 (a)-(b), where dot 1 is located prominently along the "PC 2 - Relaxation" axis, whereas dot 8 is positioned prominently along the "PC 1 - Modernity" axis.

Overall, the "clean/dirty" scale has the highest correlation with like/dislike, with an average coefficient of 0.57. This suggests that the observers tended to like paintings with clean colours rather than those with dirty colours.

Conclusions

In this study, a psychophysical experiment investigated the influence of painting category on the visual impact of colours. Principal component analysis (PCA) classified the 10 colour emotion scales into 3 principal components, "modernity", "relaxation" and "warmth", accounting for 87.7% of the total variance. The 3 principal components correspond to the common structure of colour emotion factors: chroma-related, lightness-related and hue-related [5-17].

The PCA also revealed that among the 10 colour emotion scales, only "like/dislike" exhibited a wide spread of data points in the principal component plots, indicating a significant effect of painting category on colour preference for painting images, as illustrated in Figures 7a-b. Interestingly, in early research of colour emotion, the like/dislike scale was the only one that exhibited strong cultural differences, showing inconsistent trends in colour preference across different regions of the world [12-13, 17].

The distribution of like/dislike dots in Figures 8a-b suggests that different painting categories were associated with distinct key colour emotions influencing liking. Dots 7 and 8 in the graphs, both representing the like/dislike responses for the digital paintings, are located far apart, suggesting that the like/dislike response was influenced not only by the painting medium but also by the painting style. It is intriguing to consider that painting style might be more influential than the painting medium. However, further research and verification with samples in various styles are needed to confirm this hypothesis.

Overall, this study highlights that the influence of painting medium and painting style on the visual impact of colours was primarily evident in the like/dislike scale. In other words, except for like/dislike, the visual impact of colours appears to be largely independent of both the painting medium and style. This finding could serve as a valuable resource for future research on colour combinations in paintings.

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