Colour Emotion Models, CIELAB Colour Coordinates, and Iranian Emotional Responses

Minoo Rostami, Hossein Izadan and Forough Mahyar

Abstract— **Ten colour emotional scales, namely, "Warm Cool", "Active-Passive", "Like-Dislike", "Clean-Dirty", "Fresh-Stale", "Modern-Classical", "Heavy-Light", "Hard-Soft", "Tense-Relaxed", and "Masculine-Feminine"are investigated for single-colour stimuli in CIELAB colour space within a psychophysical experiment by forty observers. The relationships between Iranian colour emotional responses and CIELAB colour coordinates are examined. Based on the results, colours with higher values of $L^*$are associated to the emotional words, such as clean, light and soft. Colour with higher C* values are also associated to warm, modern, and masculine emotional words. Iranian colour emotional responses are also assayed in three existed colour emotional models, Li Chen Ou's, Sato's and Xin-Cheng's models, for four colour emotional dimensions, "Warm-Cool", "Heavy-Light", "Active-Passive", and "Hard-Soft" scales. Results show that the Ou's model is a fairly good predictor for "Warm-Cool" scale, while the Xin-Cheng's model is a good predictor for "Heavy-Light" and "Hard-Soft" scales. In "Active-Passive" scale, none of the existed models are found to be a good predictor for Iranian colour emotional dimension.**

Keywords: Colour emotion, CIELAB colour coordinates, colour emotion model, Iranian observers.

I. INTRODUCTION

Investigation into colour emotion has been an interesting subject for scientists and researchers [1–8]. Few colour emotional models were presented and some mathematical equations were defined to express colour emotion on the basis of different colour coordinates [3, 9, 10].

Ou and his coworkers introduced four colour emotional dimensions which are calculated on the basis of the Eauations1 to 4. “WC”, “HL”, “AP”, and “HS” are "Warm-Cool", "Heavy-Light", "Active-Passive", and "Hard-Soft" scales, respectively [3].

$$WC = -0.5 + 0.02(C^*)\cos(h-50) \quad (1)$$

$$HL = -2.1 + 0.05(100 - L^*) \quad (2)$$

$$AP = -1.1 + 0.03[(C^*)^2 + (L^* - 50)^2]^{1/2} \quad (3)$$

M. Rostami and H. Izadan are with the Department of Textile Engineering of Isfahan University of Technology, Isfahan, Iran. F. Mahyar is with Architecture and urban Design School, Art University of Isfahan, Isfahan, Iran. Correspondence should be addressed to H. Izadan (e-mail: izadan@cc.iut.ac.ir).

$$HS = 11.1 + 0.03(100 - L^*) - 11.4(C^*)^{0.02} \quad (4)$$

Where L* and C* are CIELAB lightness and chroma, respectively, and h is the hue angle of this colour space.

Sato and his scientific team [9], also suggested Equations 5 to 8 as their colour emotional scales for "Warm-Cool", "Heavy-Light", "Hard-Soft", and "Active-Passive" scales, respectively:

$$WC = 3.5[\cos(h - 50) + 1]B - 80 \quad (5)$$

$$HL = -3.5L^* + 190 \quad (6)$$

$$SH = [(3.2L^*)^2 + [2.4(1 - \Delta h_{290}/360)C^*)^2]^{1/2} - 180 \quad (7)$$

$$DYP = [0.6(L^* - 50))^2 + (4.6(1 - \Delta h_{290}/360)C^*)^2]^{1/2} - 115 \quad (8)$$

where, in these equations, Δh_{290} is the difference between the hue angle of the colour of each sample and hue angle equal to 290 degrees. The value of B is calculated by Equation 9.

$$B = 2000(1 - \Delta h_{200}/360)C^*/[L^*(100 - L^*)] \quad (9)$$

In Equation 9, Δh_{200} is the difference between the hue angle of the colour of each sample and hue angle equal to 200 degrees, and L* and C* are CIELAB lightness and chroma values, respectively.

Xin-Cheng [10] as it has been quoted by Ou [3] suggested the Equations 10 to 13 for the hue angles in the range of $0 < h \leq 180$.

$$WC = 0.154L^* + 39.378C^{*(0.372)} - 0.303h - 113.855 \quad (10)$$

$$HL = -3.340L^* + 0.476C^* + 0.037h + 175.467 \quad (11)$$

$$DyPa = -0.296L^* + 3.162C^{*(0.931)} - 0.073h - 68.835 \quad (12)$$

$$SH = 2.900L^* - 0.510C^* - 0.051h - 146.700 \quad (13)$$

For all hues which are in the range $80 < h \leq 360$, Equations 13 to 16 are applied in the Xin-Cheng model.

$$WC = 0.3554L^* + 23.476C^{*(0.429)} - 0.159(360 - h) - 105.710 \quad (14)$$

$$HL = -3.3477L^* - 0.264C^* + 0.072(360 - h) + 182.866 \quad (15)$$

$$DyPa = -0.120L^* + 4.385C^{*(0.864)} + 0.032(360 - h) - 84.791 \quad (16)$$

$$SH = 2.953L^* + 0.424C^* - 0.020(360 - h) - 139.795 \quad (17)$$

where “WC”, “HL”, “DyPa”, and “SH” are respectively"Warm-Cool", "Heavy-Light", "Active-Passive", and "Hard-Soft" colour emotional scales. All variables in the Xin-Cheng’s model equations are CIELAB coordinates.

It seems there is no important difference between Ou's and Sato's models, except that Ou's model is simplified and also optomised, on the basis of his available data. However, Xin-Cheng's model seems to be extracted just by using a multiple regression technique on the emotional scales and the CIELAB colour coordinates, which is not the case for the other two models. Ou and Sato have extracted their models by more elaborate data mining methods.

II. Experimental

A psychophysical experiment was conducted to assess Iranian colour emotional responses for single-colour stimuli. A total of twenty colour stimuli, which were uniformly distributed in all over the CIELAB colour space, were randomly displayed on a "LaCie324i" LCD computer display, individually. Forty observers including seventeen males and twenty three females, who passed the Ishihara colour vision test successfully, assessed the colour stimuli. All observers were Iranian university students in the age range of 20 to 30 years old. Each colour stimulus was scored in the range of -5 to +5 for different colour emotional scales. For instance, in the "Warm-Cool" scale, -1 to -5 were associated to "Coolness", as in contrast, +1 to +5 were affiliated to "Warmth".

To investigate the relationships between colour emotion and colour coordinates, the Pearson product-moment correlation coefficient (r) were measured among colour coordinates and ten different colour emotional responses, i.e. "Clean-Dirty", "Heavy-Light", "Hard-Soft", "Warm-Cool", "Modern-Classical", "Tense-Relax", "Fresh-Stale", "Feminine-Masculine", "Active-Passive' and "Like-Dislike". As seen in Table 1, the colours with higher values of L^* associate to the emotion words, such as clean, light and soft. The colours with higher values of C* values also associate to warm, modern, and masculine emotion words.

TABLE I
THE PERSON PRODUCT-MOMENT CORRELATION COEFFICIENT (R) BETWEEN COLOUR EMOTION AND COLOUR COORDINATES

	L^*	a^*	b^*	C^*	h_{ab}
Clean – Dirty	0.64	-0.09	-0.04	0.25	0.09
Heavy – Light	-0.86	0.16	0.08	0.12	0.02
Hard – Soft	-0.81	0.19	0.13	-0.04	-0.06
Warm – Cool	-0.17	0.58	0.67	0.70	-0.44
Modern – Classical	0.02	0.34	0.29	0.81	-0.06
Tense – Relaxed	-0.59	0.42	0.46	0.38	-0.31
Fresh – Stale	0.51	0.14	-0.08	0.43	0.11
Feminine – Masculine	-0.29	-0.37	-0.18	-0.59	0.03
Active – Passive	-0.17	0.52	0.03	0.41	-0.04
Like – Dislike	0.37	0.13	-0.31	0.20	0.24

To further investigate the relationship among the colour coordinates and emotional scales, bubble charts are plotted for the four selected colour emotional scales based on different colour coordinates. In these charts the white bubbles show the word, such as, cool, light, passive and soft and the grey ones show the words, such as, warm, heavy, active, and hard. Also, the size of the bubble represents the value of the corresponding emotion (see Figures1 to 10).

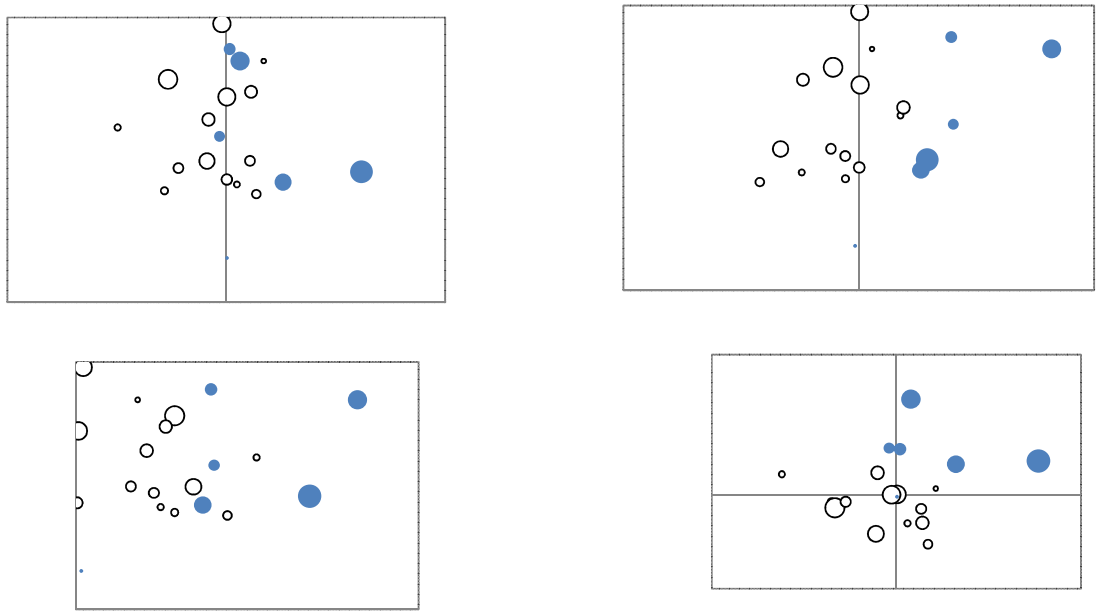

Fig. 1. Bubble charts for Warm-Cool emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

As seen in the Figure 1, red, orange, and yellow colours are associated to warmth and the blue and green colours are associated to coolness.

Figure 3 shows that the grey bubbles, which indicate active emotion, are mostly located in the right region of L*-a* plot, where colours with positive a* values are located. Also, there is not a strong relationship between the "Active-Passive" emotional scale and C* values. This observation is different by the finding of Ou's research where there is no significant relationship between this emotional scale and a* coordinate and only "the colours in the outer layer of the CIELAB space tended to be "more active" than those in the central area" [2].

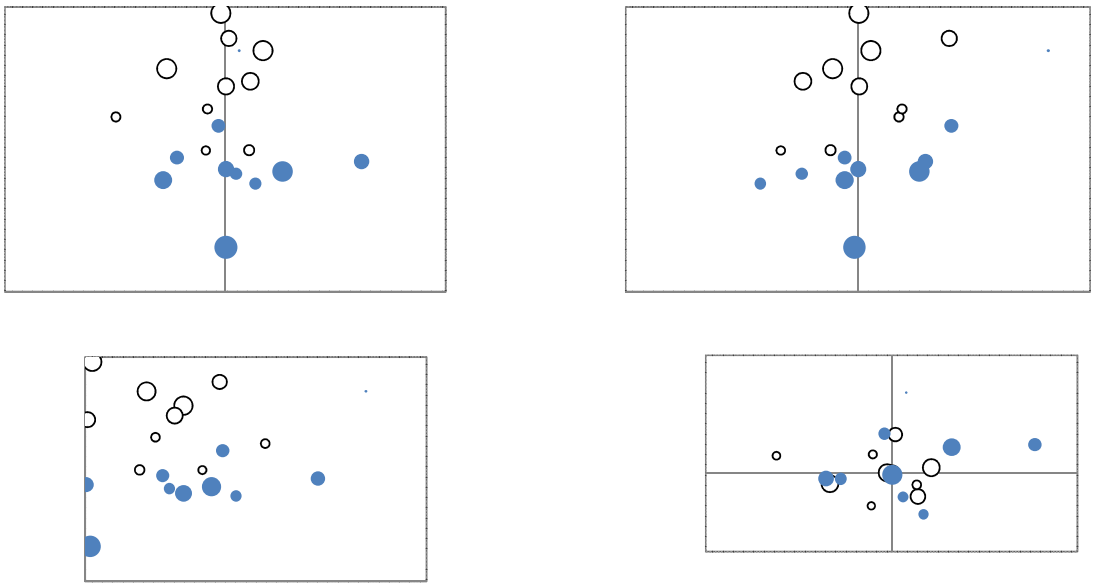

Fig. 2. Bubble charts for Heavy-Light emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

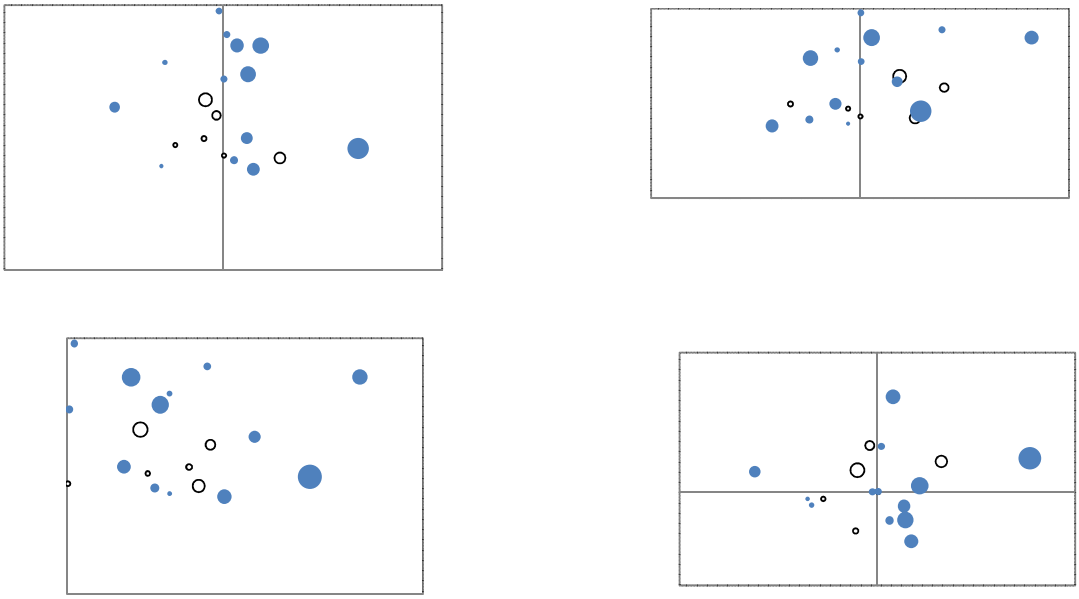

Fig. 3. Bubble charts for Active-Passive emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

As shown in Figure 4, the trend in "Hard-Soft" scale is similar to the "Heavy-Light" one. This means that lower L* values are associated with hardness.

As seen in Figure 5, the grey bubbles stand for freshness and the white ones signify staleness emotions. The less L^* values induce staleness emotion. As the Pearson product correlation coefficients between fresh-stale emotion scale and L^* values are fairly good(0.51), lightness value is a decisive criterion to characterized the freshness and staleness of a colour. Patterns in Bubble charts of Fresh-Stale, Heavy-Light and Hard-Soft are similar and the L^* values relates to the aforementioned scales, accordingly.

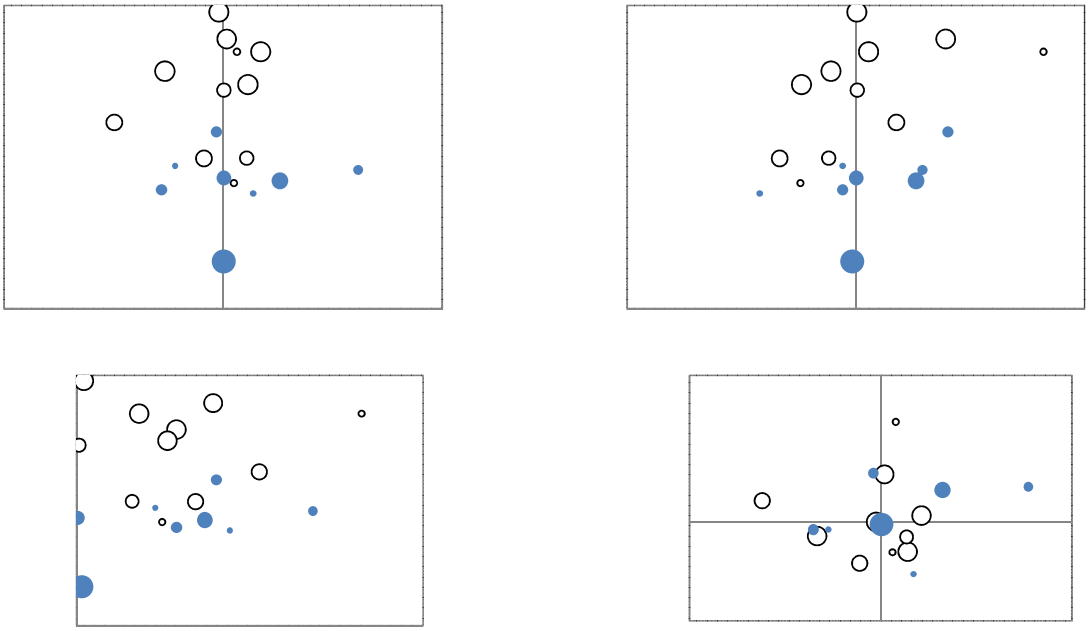

Fig. 4. Bubble charts for Hard-Soft emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

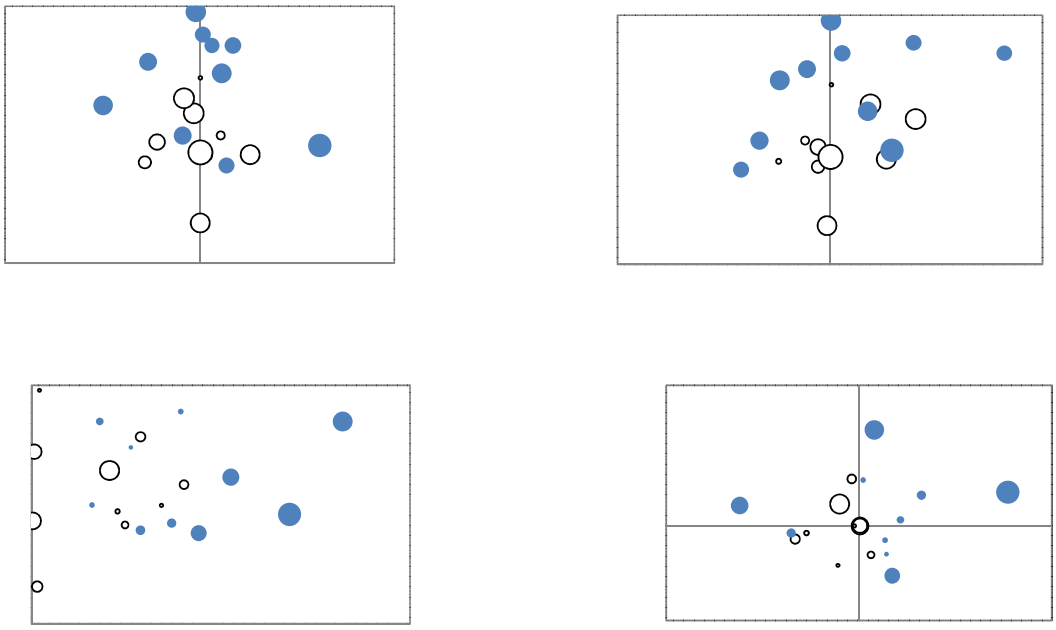

Fig. 5. Bubble charts for Fresh-Staleemotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

In Figure6, the grey bubbles show masculine and the white ones represent feminine emotions. The Pearson product correlation coefficients between masculine-feminine emotion scale and C^* values are fairly good (-0.59), and thus C* values can be considered as an influential criterion to decide if a colour induce each of the masculine or feminine emotions. According to Figure 7, there are no noticeable relationships between CIELAB colour coordinates and Like-Dislike word pair scale. So, same conclusion can be made from the results in Table I.

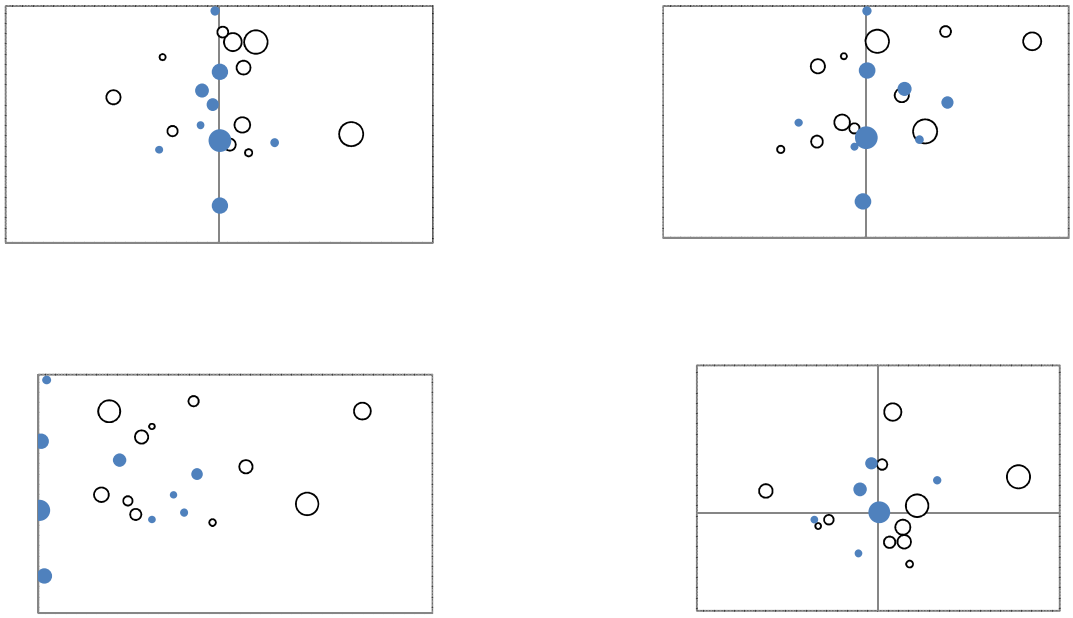

Fig. 6. Bubble charts for Feminine-Masculine emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

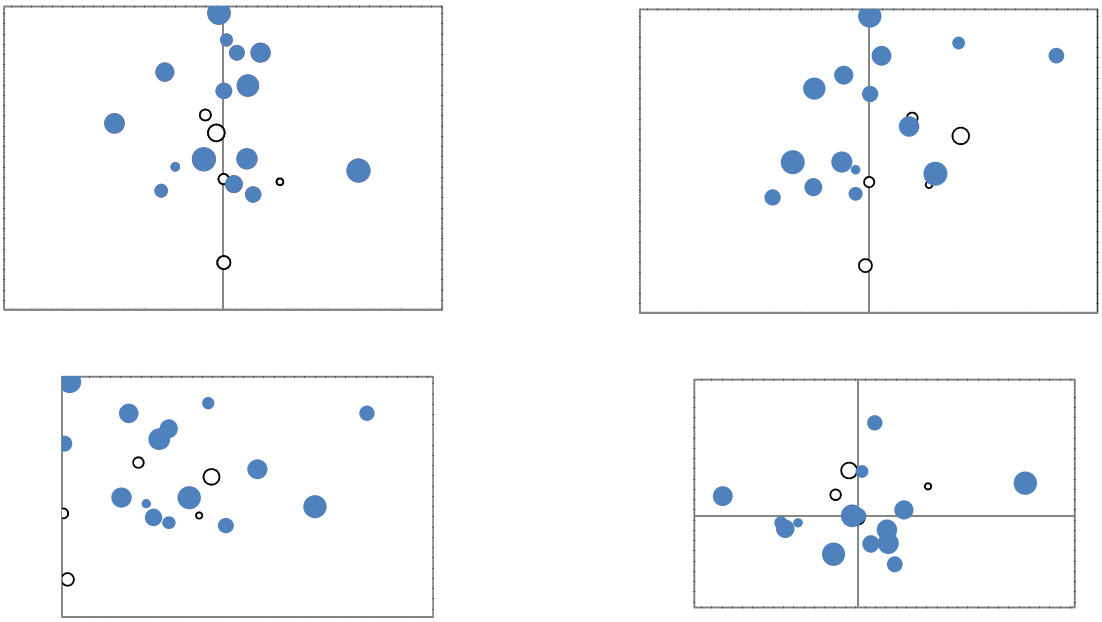

Fig. 7. Bubble charts for Like-Dislike emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

Figure 8 shows that the white bubbles, which illustrate classical emotion, are located in the central range in each plot and the grey bubbles, which demonstrate modern emotion, go towards outside the plots. Consequently, it can be concluded that the colours with high values of C^* were mostly assessed as colour which induce modern emotion and colours with low C* values are generally associated to classical emotion. Due to the high amount of the correlation coefficients between C^* value and modern-classical emotion scale (0.81), C^* value is a touchstone for showing a modern-classical emotion by a colour. In Figure 9, the grey bubbles represent tense emotion and the white ones symbolize relaxed emotion. The figure reveals that less lightness value induces more tense emotion. As seen in Table1, the correlation coefficients between L^* values and tense-relaxed emotion is -0.59, which is fairly good, and this confirms that the lightness values is an essential factor in modeling tense-relaxed emotion, accordingly.

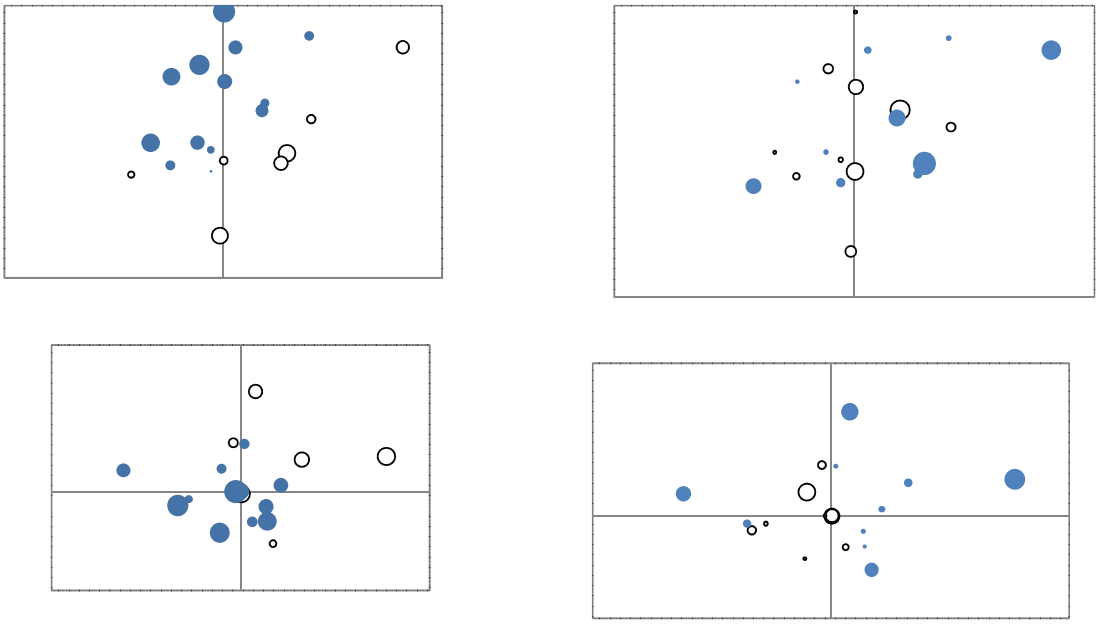

Fig. 8. Bubble charts for Modern- Classical emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

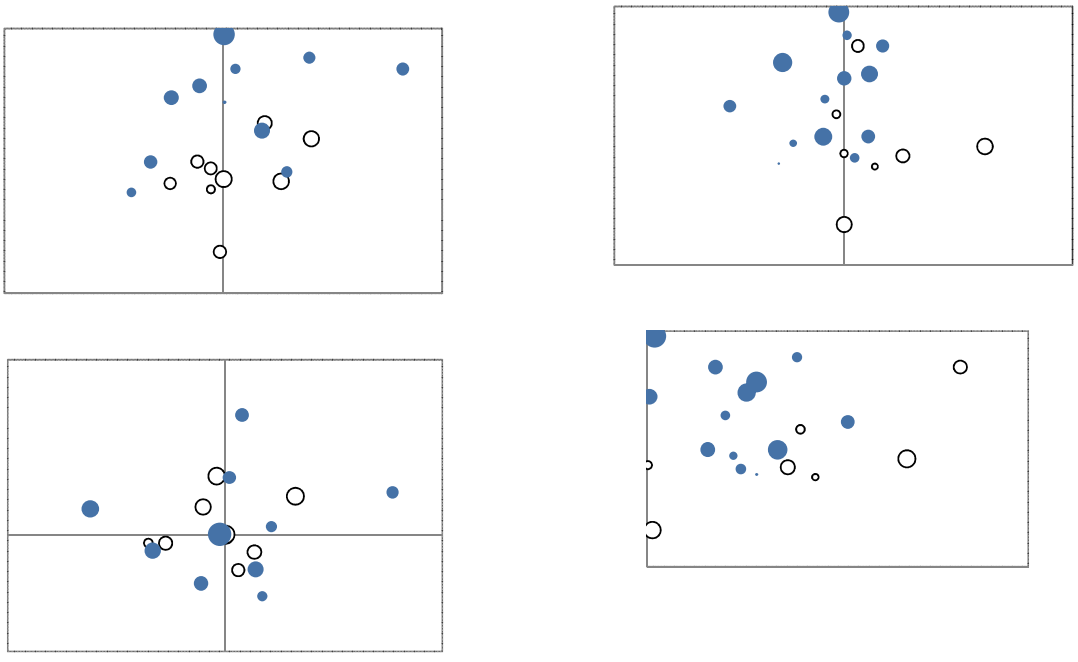

Fig. 9. Bubble charts for Tense-Relaxed emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

Figure 10 shows the alteration of the Clean-Dirty emotion by varying the different CIELAB coordinates. Based on the figure, the colours with less lightness values can be classified as dirty colours. The patterns in the plots for Clean-Dirty emotion are similar to the ones in the Heavy-Light, Hard-Soft, and Fresh-Stale emotions. The Pearson product correlation coefficients between the Clean-Dirty emotion scale and L^* value is 0.64, and thus the amounts of lightness of the products' colour affect on the Clean-Dirty emotion.

Other researchers mostly focused on four colour emotional dimensions, namely, "Warm-Cool", "Heavy-Light", "Active-Passive", and "Hard-Soft" [3,9,10]. Therefore, in the present research, the investigations to find the relationships among colour emotion in different colour emotional models were done on the four aforementioned emotional dimensions. To find which colour emotional model can predict Iranian colour emotional responses better than the other ones, data of the present research were examined in all three existed colour emotional models, namely, Ou's, Sato's, and Xin-Cheng's models. Therefore, the coefficient of determination, R^2criterion was used in order to evaluate the performance of the models by the data obtained in the present research. Results are shown in Table II, which illustrates that:

a) In Warm-Cool scale: the Ou's model is a fairly good predictor which outperformed the other two models. The Sato's model also predict the results of the present research fairly good;

b) In Heavy-Light scale: the Xin-Cheng's model is a good predictor and the Ou's and Sato's models can predict it, properly;

c) In Active-Passive scale: none of the models are able to estimate the results of the present research;

d) In Hard-Soft scale: all of the models can predict the results of the present research properly; however, the Xin-Cheng's model is superior.

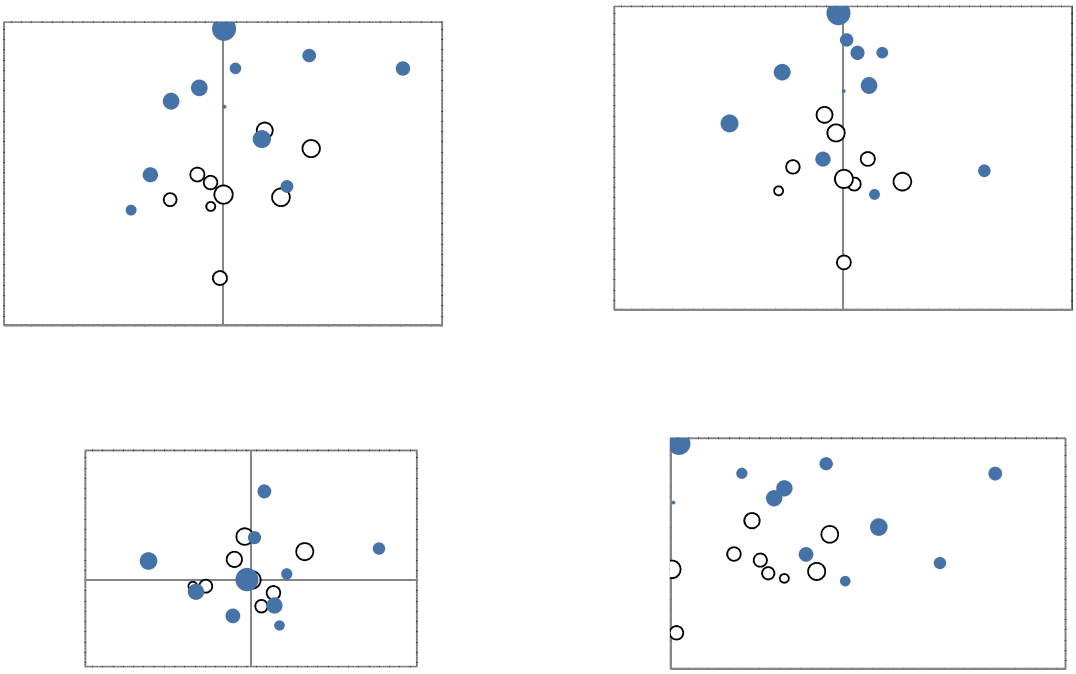

Fig. 10. Bubble charts for Clean- Dirty emotional scale in L^*a^* (top-left), L^*b^* (top-right), L^*C^*(bottom-left) and a^*b^* (bottom-right) axis.

TABLE II
COMPARISON OF DIFFERENT COLOUR EMOTIONAL (THE RELEVANT R^2 VALUES FOR EACH MODELS)

	Li Chen Ou [2]		Sato [2]		Xin –Cheng [2]	
	Ou data	Present data	Sato data	Present data	Xin data	Present data
Warm-Cool	0.74	0.69	0.82	0.62	0.77	0.48
Heavy-Light	0.76	0.74	0.90	0.74	0.95	0.85
Active-Passive	0.75	0.23	0.87	0.28	0.95	0.16
Hard-Soft	0.73	0.60	0.82	0.66	0.92	0.74

The performances of the Xin-Cheng's and Sato's models for the data of the Ou's research are given in Table III.

TABLE III
THE PERFORMANCE OF XIN-CHENG'S AND SATO'S COLOUR EMOTIONAL MODELS (THE RELEVANT R^2 VALUES FOR EACH MODELS) FOR OU'S DATA [15].

	Sato [15]	Xin –Cheng [15]
Warm-Cool	0.69	0.45
Heavy-Light	0.79	0.81
Active-Passive	0.59	0.52
Hard-Soft	0.53	0.50

Comparison of the data in Tables II and III show that the "Active-Passive" scale prediction of the both models is fairly good for the Ou's data. However, the results of the present research do not seem to be well predicted by the "Active-Passive" scale of the Ou's mode. If the results obtained from the Figure 3 is recalled, it can be concluded that Iranian "Active-Passive" scale profile is not similar to those of the previous researches. This dissimilarity of the observations for the Iranian Active-Passive emotional scales and other corresponding reported scales is likely to be the considerable contribution of a* values in Iranian response to this scale, which is not the case for the other nations' responses [15]. Therefore, a new Active-Passive model for Iranian should be developed.

III. CONCLUSIONS

The emotional dimensions of twenty single-colour stimuli were investigated through a psychophysical experiment by forty observers. Ten colour emotional scales were assessed and the relationships between the colour emotional scales and CIELAB colour coordinates were investigated. The results indicate that the colours with higher values of L^* associate to the emotions such as cleanliness, weightlessness, freshness and softness. The colours with higher values of C* also associate to warm, modern, and masculine emotions. Also, red, orange and yellow colours tend to be warm. The Like-Dislike scale shows no relationship by any of the CIELAB coordinates. This latter observation is likely to be due to the fact that Like-Dislike scale is a colour preference scale, which is different among the observers.

Four colour emotional dimensions namely, "Warm-Cool", "Heavy-Light", "Active-Passive", and "Hard-Soft", which were investigated in different existed colour emotional models, were examined using the data obtained in the present research. Results showed that the Ou's model is a fairly good predictor for "Warm-Cool" scale. The Xin-Cheng's model was found a good predictor for Heavy-Light and Hard-Soft scales. In "Active-Passive" scale, none of the existed models were a proper predictor of the results. This can be concluded that either an Iranian colour emotion model or an international "Active-Passive" model should be scrutinized.

Acknowledgements

This research was financially supported by Isfahan University of Technology, Isfahan, Iran. The authors would like to thank all the observers who participated in the experiment.

REFERENCES

[1] M. Rostami, H. Izadan and F. Mahyar, "Colour emotion: dimensions and relations; A case study among Iranian students", In: AIC2013. UK; pp 220-224, 2013.
[2] M. Rostami, H. Izadan, F. Mahyar,"Iranian colour emotional dimensions", J. Text. Polym., [Online],vol.2, no.2, pp. 51-55, 2014.
[3] L.C. Ou, M.R. Luo, A. Woodcock, A. Wright, "A study of colour emotion and colour preference. Part I: colour emotions for single colours", COLOR RES. APPL., vol. 29, pp. 232-240, 2004.
[4] L. C. Ou, M. R. Luo, A. Woodcock, A. Wright, "A study of colour emotion and colour preference. Part II: colour etotions for two-colour combinations", COLOR RES. APPL., vol. 29, no. 4, pp. 292–298, 2004.
[5] L. C. Ou, M. R. Luo, P. L. Sun, N. C. Hu, H. S. Chen, S. S. Guan, A. Woodcock, J. L. Caivano, R. Huertas, A.Treméau, M. Billger, H. Izadan, K. Richter, "A cross-cultural comparison of colour emotion for two-colour combinations", COLOR RES. APPL., pp.23-43, 2010.
[6] X. P. Gao, J. H. Xin, T. Sato, A. Hansuebsai, M. Scalzo, K. Kajiwara, S. S. Guan, J. Valldeperas, M. Jose´Lis, M. Billger, "Analysis of cross-cultural color emotion", COLOR RES. APPL., vol.32, pp. 223-229, 2007.
[7] H. Suk, H. Irtel, "Emotional response to color across media", COLOR RES. APPL., vol. 35, pp. 64-77, 2010.
[8] S.Westland, K. Laycock, V. Cheung, P. Henry, F. Mahyar, "Colour harmony", Colour: Design & Creativity, no.1, vol.1, pp.1-15, 2007.
[9] T. Sato, K. Kajiwara, H. Hoshino and T. Nakamura, "Quantitative evaluation and categorising of human emotion induced by colour", Advances in Colour Science and Technology, no.3, pp.53-59, 2000.

[10] J. H. Xin, K. Cheng, "Quantitative evaluation of colour emotion", in: Proceedings of JSPS Fund Meeting, pp.71-86, 2000.
[11] J. Hogg, "A principal components analysis of semantic differential judgments of single colors and color pairs", J. Gen. Psychol., vol.80, pp.129-140, 1969.
[12] S. S. Stevens, "Psychophysics", John Wiley & Sons, 1975.
[13] S.S. Stevens, R.C. Atkinson, R.J. Herrnstein, G. Lindzey, R. D. Luce, "Stevens' Handbook of Experimental Psychology", Learning and Cognition, vol. 2, John Wiley & Sons, 1988.
[14] D. Y. Tzeng, R. S. Berns, "A review of principal component analysis and its applications to color technology", COLOR RES. APPL., vol.30, pp.84-98, 2005.
[15] L. C. Ou, "Quantification of colour emotion and colour harmony", Ph.D dissertation, University of Derby, Derby, UK, 2004.