Optimised Parameters for CIECAM02 Based Upon Surround Size Effect

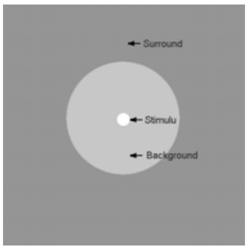
Chenyang Fu and M Ronnier Luo
Department of Colour and Polymer Chemistry, University of Leeds, United Kingdom

Abstract

This study investigates the effects of the size and the luminance value of the surround field on colour appearance under various viewing conditions. Ten phases of psychophysical experiments were conducted to obtain visual data assessed by a panel of 10-15 observers. The viewing conditions investigated include two sizes of surround field, three viewing distances, two luminance values of surround and three different sizes of stimuli. The accumulated visual data sets were used to test the CIE colour appearance model, CIECAM02[1], and the results showed that CIECAM02 gave a satisfactory prediction. Finally, the viewing parameters F, N_c and c in CIECAM02 were optimised to fit colour appearance results under different surround conditions. It was found a very small improvement.

INTRODUCTION

Usually we observe coloured objects in a complex environment. Surround is one of the most important factors for determining the viewing conditions affecting colour appearance. The CIECAM02[1] is the colour appearance model recently recommended by CIE. Colour appearance model plays a key role in achieving successful colour image reproduction across different media under distinct viewing conditions. In order to apply the model correctly, there is a need to understand viewing parameters defined in the CIECAM02. Figure 1 defines three viewing fields: adapting field, background and surround as defined below:-



- *Adapting field:* everything in the visual field outside of the stimulus.
- *Background:* a roughly 10 degree region immediately surrounding to the stimulus.
- *Surround:* the field outside the background[2].

Figure 1: *The region of fields used in colour appearance models*

In CIECAM02, three types of surround are defined by surround ratios (S_R), i.e. ≥ 0.2, <0.2 and 0, corresponding to surrounds of *average*, *dim* and *dark*, respectively. S_R is a ratio between the luminance value of a reference white in the surround area (denoted as L_{SW}) and that in the display area (L_{DW}). Therefore, CIECAM02 model only considers the surround conditions according to the luminance value ratio. It does not consider the size of surround field, which could also make an impact on colour appearance.

After S_R value is obtained, the viewing condition is defined, and accordingly viewing parameters of *F* (incomplete adaptation factor), *c* (lightness surround induction factor) and N_c (chromatic surround induction factor) are then determined as given in Table1.

Table 1 Surround parameters and surround ratio S_R used in the CIECAM02

	c	N_c	F	S_R
Average surround	0.69	1.0	1.0	≥ 0.2
Dim surround	0.59	0.9	0.9	< 0.2
Dark surround	0.525	0.8	0.8	0

Since CIECAM02 model only considers the surround conditions according to the luminance value, the size of surround field has not been involved. In this study, particularly interest was paid to the investigation of surround size effects. Figure 2 illustrates the viewing field in the experiment. The whole field was divided into two areas: '*display*' and '*surround*', which are opposite to each other. A larger the surround field is, a smaller display field will be. This is also dependent on the viewing distance. A longer the viewing distance is, the smaller display field (or the larger surround field) will be.

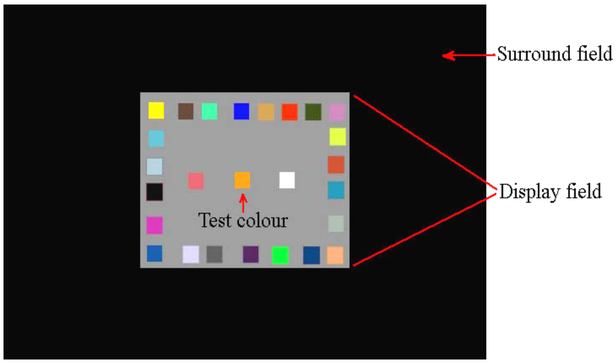


Figure 2: *The display and surround field in the whole viewing area in the experiment*

EXPERIMENTAL CONDITIONS

A CRT monitor with a 24-bit graphic card was used to display colour stimuli. It was adjusted to a correlated colour temperature of 6500K with a luminance of the CRT's white point of 67 cd/m^2. The CRT monitor was carefully characterised using the GOG (gain-offset-gamma) model[3].

A viewing environment was arranged using a CRT monitor surrounded by a paper cardboard. Two surround conditions were under investigation, i.e., the *dark* and *average* conditions. The luminance of the CRT peak white was taken as the device white (L_{DW}). The average surround condition was simulated using a D65 simulator hung from the ceiling. Note that a black cardboard was used in the *'dark'* surround condition (dark room) and a white cardboard in the *'average'* surround condition. The white cardboard was selected to have similar colorimetric values to the colour of the wall in the experimental room.

Forty colour patches were carefully selected to cover a wide colour gamut and lightness range. Each was displayed in the centre of the CRT monitor and was measured using a Minolta CS1000 tele-spectroradiometer (TSR) to obtain tristimulus values. Figure 2 also shows the viewing pattern used in the experiment which was similar to the one used in the LUTCHI[4] experiment. It included a test colour, a reference white and a reference colourfulness patch. Table 2 summarises the viewing conditions in each phase.

Ten phases of psychophysical experiments were conducted. Each colour was assessed in terms of lightness, colourfulness and hue by 10-15 observers using the magnitude estimation method[4].

The name of each phase is composed of four parts. The first part describes viewing distance at 300, 30 and 70 cm. The second part expresses the surround condition, i.e. D and A correspond to dark and average surround conditions, respectively. The third part states the sizes of stimuli and display field in terms of degree. For example, 30D2-34 denotes that a 2° stimulus is viewed on a 34° display field at a 30cm distance for dark surround condition. Note that the viewing angles of surround field plus the display field represent the full viewing field. Thus the angular subtense of the display field also reflects that of the surround field.

In phases 1 to 6, the physical sizes of colour patches were varied from 8cm×8cm to 1cm×1cm for investigating the effects of the sizes of stimuli. The colour patches with the same physical size had different viewing angles at different viewing distances.

In phases 1 to 8, the size of display field (or surround field) was fixed, but its angular subtense was changed according to the viewing distance: 300cm, 30cm and 70cm. For further investigation of the effect of surround size, the size of the display field was changed in phases 9 and 10 with the same viewing distance as phases 7 and 8 (70cm). Figure 3 illustrates large and small display fields used in the experiment which had 34° (left) and 12° (right) angular subtense, respectively. Note that test colours were located in the middle of the display area, with a size of 2° field in phases 3, 4, 7 and 9.

In phases 7 to 10, dark and average surround conditions were investigated. Note that in phases 8 and 10, for the average surround condition, the luminance value was much higher than those in phases 7 and 9 for dark surround condition.

Table 2: The viewing conditions in the 10 experimental phases studied

Phase (Name)	Distance (cm)	Angular subtense of display field	Angular subtense of test colour	Surround condition
1 (300 D 0.2-8) 2 (300 D 0.4-8) 3 (300 D 2-8)	300	8°	0.2° 0.4° 2°	Dark
4 (30 D 2-58) 5 (30 D 5-58) 6 (30 D 15-58)	30	58°	2° 5° 15°	Dark
7 (70 D 2-34) 8 (70 A 2-34)	70	34°	2°	Dark Average
9 (70 D 2-12) 10 (70 A 2-12)	70	12°	2°	Dark Average

RESULTS

The visual data were collected and the coefficient of variation (CV) was used to indicate the agreement between two sets of data. Note that for perfect agreement, the CV value should be zero. A CV of 30 represents about 30% variation between two datasets. The results show that the mean CV values for observer repeatability and accuracy are 11, 17, 5 and 17, 27, 9 for lightness, colourfulness and hue, respectively. The results are reasonable agreed with those found by Luo *et al*[4].

In the previous study[5], the effect of surround field sizes was investigated by making comparisons between phases with the same 2° stimuli, but different viewing field of surround. It was found a weak tendency that a smaller display field (or larger surround field) induces a lower lightness contrast and a higher colourfulness. In general, for hue attribute, differences in colour appearance between each of the comparisons were small. For the effects of surround luminance levels, a weak trend was also found that dark colours appear lighter and a slight colourfulness reduction in high-level luminance viewing condition. It should be noted that the visual results gathered from previous study indicate that the surround size effect is not significant.

The visual data gathered was also used to evaluate the performance of existing colour appearance model, CIECAM02 and the results were also reported in the previous study. The CV value was again used to indicate the agreement between visual results and CIECAM02 predictions. In general, CIECAM02 prediction shows a reasonable good agreement with visual results, i.e. the mean prediction errors are almost the same as the observers accuracy based on a panel of 10 to 15 observers. However, there is a weak trend that lighter colours have higher lightness than visual results. For colourfulness, CIECAM02 prediction shows a trend of reduction except scattering results found in very small viewing angle of stimuli. For hue, there is hardly and difference between visual results and CIECAM02 predictions

Note that the viewing parameters in CIECAM02 related to surround condition are *F, c and* N_c which were discussed early. They are decided by three categories of surround ratios, i.e. $S_R \geq 0.2$, $S_R < 0.2$ and $S_R = 0$, corresponding to three types of surround, *average*, *dim* and *dark*, respectively. S_R is a ratio of the luminance value of the reference white in the surround area to that in the display area. Based on this definition, phases 8 and 10 were conducted under average surround condition (*S_R> 0.2)* and other phases were under dark condition (*S_R=0)*. In other word, phases 8 and 10 had the same viewing parameters, that being *F=1, c=0.69* and N_c *=1;* and other phases had the same ones as *F=0.8, c=0.525* and *N_c=0.8.* This means that different surround sizes corresponding to the same viewing parameters which could be optimised for achieving better model performance.

In order to find out the optimised parameters for CIECAM02 to improve its performance of colour appearance prediction under different surround conditions in this study, *"new"* viewing parameters were derived by minimising the sum of the CV value between of each appearance attribute for each phase, and the predicted value of that attribute. Subsequently, the optimised viewing parameters (*F, c and N_c*) in CIECAM02 were found which were changed according to viewing conditions studied. The results are summarised in Table 3.

With the purpose of finding the changes in colour appearance caused by the surround size effects, the experimental results were reorganised to remove the influence due to the variation of viewing conditions. Phases 3, 4, 7 and 9 which had a constant 2° (angular subtense) stimuli but different sizes of display field were used to investigate the relationship between viewing parameters (*F, c and N_c*) and surround field size.

It was found that there is a very slight change in the values of optimised parameter *F* by varying surround sizes. This implies that the surround size effects possibly have no relationship with viewing parameter *F*. Therefore, the optimised parameter *F* was taken as a constant; only the other two optimised viewing parameters N_c and *c* are plotted against display sizes in Figure 3.

Table 3: Summary of optimised viewing parameters in CIECAM02 of 10 phases

Name	300D0.2-8	300D0.4-8	300D2-8	30D2-58	30D5-58	30D15-58	70D2-34	70D2-12	70A2-34	70A2-12
Phase	1	2	3	4	5	6	7	9	8	10
S_R	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.10	1.10
F	1.18	1.12	1.18	1.17	1.06	1.18	1.18	1.18	1.17	1.17
c	0.71	0.68	0.62	0.63	0.60	0.60	0.65	0.63	0.75	0.73
Nc	0.99	0.97	1.05	0.94	1.00	1.02	0.99	1.01	1.19	1.18

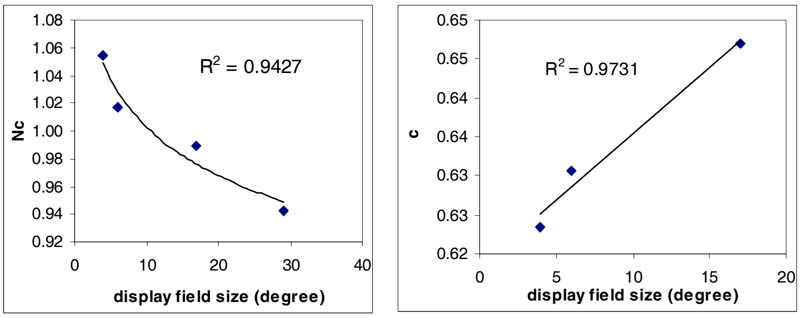


Figure 3: *Relationship between N_c (left) and c (right) with display sizes*

It can be seen in Figure 3 that N_c decreases when display field size increases. This agrees well with the visual results, i.e., small display field induces higher colourfulness. Since these 4 phases were all conducted under dark surround condition, the original values of viewing parameters N_c and *c* in CIECAM02 should be considered, i.e., 0.525 and 0.8, respectively. As a result, the optimised parameters can be calculated by equation (1).

$$N_{c-new} = N_c \times Ln(size) \times (-0.063) + 1.4$$

$$c_{-new} = c \times (0.002 \times size + 1.15)$$

$$F_{-new} = 1.18 \qquad (1)$$

Using these new viewing parameters, the colour appearance attributes lightness, colourfulness and hue composition were predicted via the CIECAM02 mode. The CV value was used to indicate the agreement between visual results and CIECAM02 new predictions. Table 4 shows the CV value calculated with and without using the optimised viewing parameters of all 10 phases. The values of CV-L, CV-M, and CV-H were computed using the original CIECAM02 viewing parameters. The values of CVnewL, CVnewM and CVnewH were calculated using the revised CIECAM02. Note that colourfulness calculated using the individual gradient (not the mean scaling factor) in Table 4. The results for the 4 most affected phases are given in bold.

The mean CV values showed that it gave a slightly improvement in colourfulness prediction, i.e., the predicted errors (16, 23 and 9 units respectively) are smaller than or close to the model predictions using the original viewing parameters (16, 25 and 9 units respectively). In conclusion, colour appearance does not change much due to the size of display and CIECAM02 gave an overall satisfactory performance.

CONCLUSIONS

In general, the surround size effect found in this study was small. There was only a slight weak trend that a smaller display field (or larger surround field) induces a lower lightness contrast and a higher colourfulness. However, CIECAM02 gave an overall good agreement with visual results. The model was further slightly improved, especially for colourfulness prediction. It is not recommended to apply the refined model due to very small difference between the original and refine models.

Table 4: Testing performance of the CIECAM02 with and without optimised parameters in terms of CV values for 10 phases

	Using original parameters			Using optimised parameters		
Phase	CV-L	CV-M	CV-H	CV-L	CV-M	CV-H
1	17	35	10	14	36	9
2	17	30	11	16	32	10
3	**19**	**23**	**7**	**19**	**20**	**6**
4	**16**	**23**	**12**	**16**	**21**	**11**
5	17	21	11	17	21	10
6	16	21	7	16	21	7
7	**15**	**25**	**10**	**14**	**22**	**10**
8	15	19	10	15	19	10
9	**14**	**23**	**7**	**14**	**20**	**7**
10	14	22	10	14	20	10
Mean	**16**	**25**	**9**	**16**	**23**	**9**

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Author Biography

Chenyang Fu is a PhD student in the Department of Colour Science in the University of Leeds. She received her BE in graphic technology from the Beijing Institute of Printing (1992). Her work is focusing on the quantification of colour appearance under different viewing conditions.