The Journal of The Institute of Internet, Broadcasting and Communication (IIBC)
Vol. 16, No. 1, pp.43-53, Feb. 29, 2016. pISSN 2289-0238, eISSN 2289-0246

http://dx.doi.org/10.7236/JIIBC.2016.16.1.43
JIIBC 2016-1-6

디스플레이상에서 주변시를 고려한 색채 인지 비교 연구

A Comparison Study of Colour Perception considering Peripheral Vision on Display Device

홍지영*, 박연선**

Ji-Young Hong*, Yun-Sun Park**

요 약 본 연구는 배경의 밝기와 색상 자극의 크기에 따라 인지될 수 있는 색상 속성이 차이가 있을 수 있다는 가정 아래, 배경의 밝기를 차등적으로 적용하여 Peripheral vision에 해당하는 10°와 20°의 자극을 colour matching하는 실험을 진행 하였다. 실험결과, 배경의 밝기 및 실험 자극으로 사용된 Munsell 색상 속성의 조합에 따라 동일한 색상임에도 불구하고 colour를 각기 다르게 인지할 수 있다는 경향성을 볼 수 있었으며, 자극의 크기에 대한 색상 인지 관련 선행 연구 결과와 다르게 배경의 밝기의 변화에 따라 색상 자극의 크기가 상대적으로 작다고 하더라도 더욱 colourful 하거나 더욱 밝게 인지될 수 있다는 결과를 얻을 수 있었다. 본 연구에서 진행된 실험 결과를 바탕으로 향후 영상의 크기가 변환 될 때 발생할 수 있는 화질 열화를 개선할 수 있으며 2D 뿐만 아니라 3D나 홀로그램 영상처리 시, 시감적 특성을 반영한 효과적인 입체 영상 재현에도 기여할 수 있다.

Abstract In this study, under the assumption that there may be differences in colour attributes that can be perceived according to the brightness of the background and the size of the colour stimulus, a test was conducted where colour matching was done for stimulus sizes of 10° and 20° in terms of peripheral vision by varying the background brightness. The test results showed that depending on the background brightness and the specific combinations of the Munsell colour attributes used as the test stimulus, colours can be perceived differently even if they are the same colours. In addition, in contrast to findings from previous studies on colour perception according to the stimulus size, it was found that even if the size of the colour stimulus is relatively small, colours can be perceived more colourfully or more brightly with changes in the background brightness. Based on the findings of this study, degradation in image quality can be improved, which may occur when the size of the input image is changed at a later time, and also, contributions can be made when it comes to the reproduction of effective sold three-dimensional structures that reflect visual qualities when processing 3D holographic imagery, in addition to 2D imagery.

Key Words : Display, 2D, 3D, Human visual perception, Peripheral vision, Colour

*정회원, 경민대학교 광고홍보제작과 조교수,
홍익대학교 디자인·공예 색채학 박사과정
**정회원, 전 홍익대학교 조형대학 교수,
(사) 한국컬러유니버설디자인협회
접수일자: 2015년 12월 17일, 수정완료: 2016년 1월 17일
게재확정일자: 2016년 2월 5일

Received: 17 December, 2015 / Revised: 17 January, 2016 / Accepted: 5 February, 2016
*Corresponding Author: placebo_joan@kyungmin.ac.kr
Ph.D. Candidate, Department of Design & Crafts, Hong Ik University, Seoul, Korea , Assistant Professor, Department of Visual Communication Design, Kyung Min College, Korea

Ⅰ. Introduction

Colour is one of the most important factors in assessing the image quality on a display device. On smart phones, TVs and other common types of display devices, colour plays an extremely important role in the assessment of image quality, and in order to improve the reproducibility of colour to fit the characteristics of the particular display and to implement independent colour imaging technology, a suitable colour appearance model is needed.

The colour appearance model is the result of expanding the basic colourimetry for predicting the appearance for many different types of surrounding environments as it relates to stimulus values such as lightness, chroma, and hue, and it describes the changes in the visual responses caused by changes in these different types of environments. That is, it refers to a mathematical model developed for 3D-based colour data processing which takes into account factors related to changes in the surrounding environment that affect a person's perception of colour as well. The size of the stimulus, which is one of the conditions that need to be met for the colour appearance model, is one of the factors that allows one to perceive colours differently even if they're the same colour. This kind of a phenomenon can occur because the rods and the cones are distributed irregularly around the retina, and there has been a study that found that the colour can be seen to be desaturated as the retina eccentricity increases[1] because the colour vision in the peripheral retina is different than that of the fovea, which also backs this idea.

The standard observer conditions established by the CIE International Lighting Commission comes in two types: the 2° observer conditions (CIE 1931), and 10° (CIE 1964) observer conditions. They are used to express the ordinary visual sensibility of an observer. It can be said that this is a major case in point that the extent of perception of colour can differ according to the size of the colour stimulus. That is, even if it is the same physical colour, it can be perceived differently depending on the size of the stimulus or on the particular environmental conditions. On the other hand, there have also been studies that found that given sufficiently large size of the stimulus and no problems with the effect of macular pigmentation or the contribution of rod signals, the colour vision of the peripheral retina is extremely similar to the colour vision of the fovea.[2,3,4]

There are studies being conducted by colour scientists on accurate reproductions of the same physical colour across different sizes, but so far there hasn't been a specific colour appearance model suggested for this[5], and furthermore no colour appearance standard has been established yet for reproducing the same colour across different sizes particularly as it relates to peripheral vision.

One of the conditions for completing a colour appearance model is the colour size effect, and one of the major previous studies pertinent to this examined the extent of colour perception for different sizes of colour stimulus under diverse types of media and observation conditions. But in previous studies, since the tests conducted did not take into account the fact that a human's visual perception is most sensitive to brightness, while we can know about the overall tendency of colour perception as the size of the colour stimulus varies, the previous findings do not adequately help in describing the characteristics of colour perception when taking into account the brightness of the background for luminescent displays.

Granted there have been studies on the colour size effect which compared printed colour chips[6] and not displays, and some which conducted tests on displays as well[7], but they did not take into account the brightness of the background and only varied the size of the stimulus.

The recent trend for display sizes is for a steady increase, and accordingly display manufacturers are greatly interested in reproducing colours accurately and in improved imagery on colour displays of various sizes. In order to meet this kind of a need, studies are needed for examining how the colour appearance changes depending on the physical size.

Accordingly, the purpose of this study is to examine what kind of an effect the brightness of the background has on the size of the stimulus, under the assumption that colour perception will differ when the size of the colour stimulus changes in the colour vision in the peripheral retina.

II. Colour vision in the peripheral retina and fovea

Colour perception can be classified into fovea vision and peripheral vision according to the receptor characteristics of the retina, which is made up of five different cell layers including the receptor nerve cells which are made up of cones and rods. The retina of a human performs basic visual data processing. The fovea of the retina is mostly made up cones, which are responsible for colour processing and provide a high resolution. But as it goes from the center to the surroundings, the distribution consists mostly of rods, which are sensitive to changes in brightness and motion, and they are not particularly about colour processing. Therefore, focal vision with cones and peripheral vision with cones are each responsible for different visual functions, and they work in parallel in a human's processing of visual information.

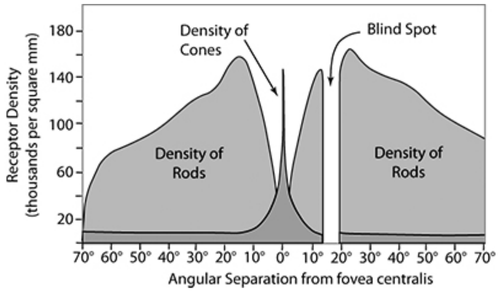

Fig. 1. Distribution of rods and cones in the human retina
그림 1. 간상체와 추상체의 분포도

The visual angle refers to the angle formed by two straight lines from both sides of an object to one's eyes. The size of this angle, whether it is large or small, determines the size of the image formed on the retina.

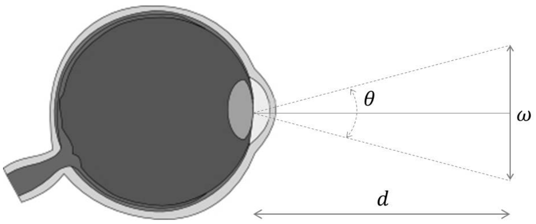

Fig. 2. Visual angle according to the size of the stimulus and distance
그림 2. 자극의 크기와 거리에 따른 시각

Typically, with one's arms stretched out, the size of the fingernail of the thumb can be estimated to be about 1.5°- 3°. As seen in Figure 2, when the size of the object and the distance are given, the visual angle can be found with Formula 1, and when the minimum visual angle (θ_{min}) and the distance (d) are given, the minimum size of the object that can be perceived (ω_{min}) can be found with Formula 2. Finally, when the minimum visual angle (θ_{min}) and the size of the object to be perceived (ω) are given, the maximum distance (l_{max}) can be found with Formula 3.

$$\theta = 2 \times \arctan\left(\frac{\omega}{2d}\right) \quad (1)$$

$$\omega = 2 \times d \times \tan\left(\frac{\theta_{min}}{2}\right) \quad (2)$$

$$d_{max} = \frac{\omega}{2} \times \cot\left(\frac{\theta_{min}}{2}\right) \quad (3)$$

The cones are concentrated within the 10° range from the center. Most accurate seeing is possible within the 2° range (in the fovea), and the accuracy rapidly decreases in the 4-5° range (parafovea). At 5°, the accuracy is reduced to about 50%.[8]

The vision of a human is mostly responsible for detecting the existence of an object and determining its location (localization), or for motion perception. Accordingly, while both the focal vision and peripheral vision are involved in trying to perceive an object, activities for object identification and recognition are mostly done by the focal vision, and the fact that colour processing depends on the cones can be seen to be related to accurate determination of the identity of the object.

As discussed, there is a lot of research activities underway related to the focal vision and the peripheral vision, and it can be seen that the vision of a human is affected by diverse types of surrounding environments and works in parallel in order to perform its function.

Ⅲ. Psychophysical Experiments

1. Test methods

In this study, the test was conducted under the assumption that there will be differences in colour perception depending on the brightness of the background, and the stimuli of 10° and 20° were used for the test, which are sizes that correspond to the colour vision in the peripheral retina.

The colour matching test method was used, which adjusts it so that the 10° and 20° stimuli are inferred to similar colours according to the brightness of the background on a luminescent display. The RGB values were inferred to CIE XYZ tristimulus values using the PLCC model (Piecewise Linear Interpolation assuming Constant Chromaticity coordinates), and these values were converted to CIECAM02 and the colour perception characteristics were compared and analyzed. The display used for the test was X-Rite i1 Pro2, and it was used after calibrating to the D65 standard illuminant.

2. Test plan

The colours used in the test were the standard 10 colours from the Munsell colour system, which are: 5R, 5YR, 5Y, 5GY, 5G, 5BG, 5B, 5PB, 5P, and 5RP.

Table 1. Munsell colours used in the test
표 1. 실험에 사용된 먼셀 색상

H	V	C	X	Y	Z
5R	4	4	14.13	12.00	9.81
5YR	4	4	13.24	12.00	6.41
5Y	4	4	11.30	12.00	4.59
5GY	4	4	9.60	12.00	5.62
5G	4	4	8.73	12.00	10.49
5BG	4	4	8.93	12.00	14.66
5B	4	4	9.88	12.00	19.28
5PB	4	4	11.64	12.00	21.06
5P	4	4	13.41	12.00	19.29
5RP	4	4	14.14	12.00	14.00
5R	4	8	17.00	12.00	7.24
5YR	4	8	14.76	12.00	2.59
5Y	4	8	11.48	12.00	1.02
5GY	4	8	8.35	12.00	1.54
5G	4	8	6.44	12.00	8.74
5BG	4	8	6.79	12.00	16.66
5B	4	8	8.72	12.00	27.78
5PB	4	8	11.93	12.00	31.52
5P	4	8	15.45	12.00	25.67
5RP	4	8	17.14	12.00	15.16
5R	8	4	62.36	59.10	55.13
5YR	8	4	60.21	59.10	43.41
5Y	8	4	54.64	59.10	35.90
5GY	8	4	50.78	59.10	37.88
5G	8	4	47.54	59.10	54.88
5BG	8	4	48.09	59.10	65.91
5B	8	4	51.03	59.10	78.62
5PB	8	4	56.02	59.10	82.57
5P	8	4	60.16	59.10	78.17
5RP	8	4	62.09	59.10	64.90
5R	8	8	70.23	59.10	45.62
5YR	8	8	64.62	59.10	26.64
5Y	8	8	54.40	59.10	18.19
5GY	8	8	46.61	59.10	21.11
5G	8	8	40.36	59.10	48.04
5BG	8	8	41.34	59.10	68.65
5B	8	8	46.40	59.10	98.59
5PB	8	8	56.12	59.10	110.80
5P	8	8	65.87	59.10	97.75
5RP	8	8	70.51	59.10	66.23

The XYZ, which are physical colourimetric values for the selected colours, were converted to CIE XYZ tristimulus values which correspond to the D65 illuminant, before they were used. As seen in Table 1, the colour stimuli selected for the test were by combining the Munsell value (V) and Munsell chroma (C) in 4 and 8 combinations.

Table 2. XYZ parameters for C illuminant and D65 illuminant
표 2. C 광원 및 D65광원의 XYZ 파라미터

XYZ	C	D65
Xwr	98.07	95.047
Ywr	100.00	100
Zwr	118.25	108.883

Table 2 shows the C illuminant, which is the basic light value of Munsell data, and the XYZ value of D65 standard illuminant. That is, since the the Munsell data are XYZ values in which the value of C illuminant is reflected, it can be said to be the XYZ parameter used in order to convert to the XYZ values which have the D65 illuminant applied.

The displays used for the test were LCD monitors, having a screen size of 22 inches, maximum resolution of 1650x1050, and all set to the D65 standard illuminant. The characteristics of the calibrated displays are as shown in the below graph.

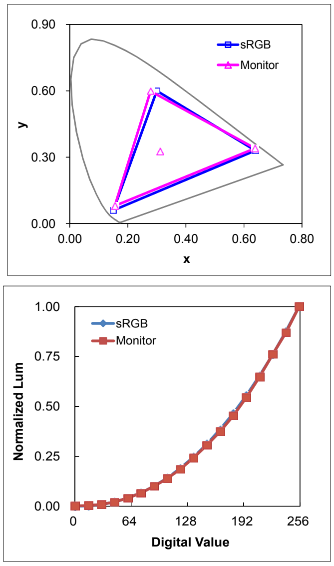

Fig. 3. Characteristics of the display used in the test
그림 3. 실험에 사용된 디스플레이의 특성

In order to infer the colours that the study participants controlled on the display as physical colourimetric values, the characteristics of the display used in the test need to be accurately analyzed beforehand, in order for more accurate analysis of differences in colour perception. Therefore, differences in colours were examined for the Munsell colours used in the test, with regard to the physical colourimetric values and the values inferred by using the PLCC model.

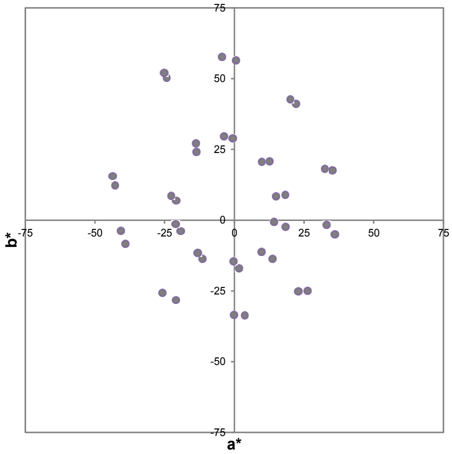

Fig. 4. Distribution of Munsell colour stimulus used in the test in the $a_c$and b_c diagrams of CIECAM02
그림 4. CIECAM02의 a_c와 $b_c$diagram상에서 실험에 사용된 Munsell 색상 자극 분포

Generally speaking, it can be said in brief that the monitor device characterization models deduce the interaction formula for the normalized luminance corresponding to the DAC (Normalized Digital to Analog Converter) of the RGB channel. One of the models that is used widely is the PLCC model, which is basically defined by making up a colour reference table for the tristimulus values XYZ and the corresponding DAC values. As a result of inferring the values using the physical colourimetric values and using the PLCC model, the value of ΔE_ab was found to be about 1.8 on average, and the Munsell colours used in the test are shown in Figure 4.

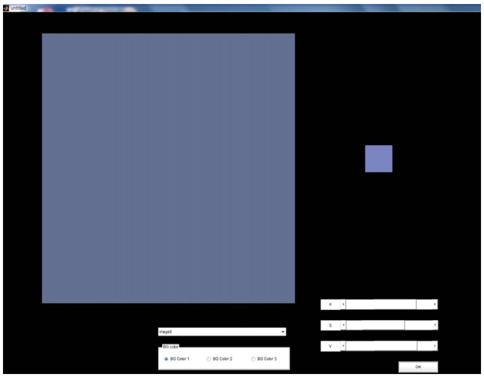

Fig. 5. Test environment set up in MATLAB
그림 5. MATLAB으로 구현된 실험 환경

The colour stimulus used in the test had the size of 10° (8.81 x 8.81cm) and 20° (18.19 x 18.19m) and it was set up so that the study participants could control the colour attributes so that they match those of the sample colours for each stimulus. The viewing distance between the display and the study participants was set fixed at 50cm and the test was conducted in a darkroom with 10 study participants with normal vision. For the lightness used for the background, in order to know more clearly the correlation between background lightness and colour stimulus, the digital value of 0, which corresponds to the darkest value, and the digital value of 255, which corresponds to the brightest value, were used in the test. To perform the colour matching test, a test environment was set up using the MATLAB software, as shown in Figure 5.

The test procedures were as follows. The study participants chose the brightness of the background and controlled the colour attributes for each of the 40 Munsell colours, namely H (Hue), S (Chroma), and V (Lightness), using a slide bar so that the colour looked the same as the sample colour. The study participants were given a plenty of time to adjust the colour attributes, and before the test was conducted they had time to adjust to the darkroom environment. When the brightness of the background changed as well, the same kind of adaptation was used so that there was no bias for brightness changes.

Ⅳ. Test results and analysis

CIECAM02, which was used for the analysis of the test, is a colour description standard that takes into account even external factors that affect colour perception, and which can quantify visual colour perception. It can be said to be the most advanced standard colour space from the CIE which reflects visual sensibility. In order to get the lightness J for CIECAM02, and chroma C, yb was set to 20 and surround condition was set to average.

Table 3. Viewing condition parameters for different surrounds
표 3. 다양한 환경에서의 각기 다른 파라미터

Surround	F	c	Nc
Average	1.00	0.69	1.00
Dim	0.90	0.59	0.95
Dark	0.80	0.53	0.80

The colour attributes calculated with CIECAM02 were analyzed using CV (Coefficient Variation), and the formula used is as follows.

$$CV = \frac{100}{\overline{y}}[\Sigma(x_i - y_i)^2/n]^{1/2} \quad (4)$$

Typically CV refers to the absolute percentage difference between two data sets. The variable n used in the formula refers to the number of stimuli used in the test, and $\overline{y}$ refers to the average of the y data set. For example, when CV is near 0, it can be interpreted that the two data sets are perfectly identical.

Table 4. CV of J (lightness) and C (chroma) according to the size of the stimulus when the brightness of the background is 0 and 255
표 4. 배경의 밝기가 0과 255인 경우 자극의 크기에 따른 CIECAM02 J(Lightness)와 C(Chroma)의 CV

BG Lightness	J(Lightness)	C(Chroma)
0	12.33	18.36
255	7.03	30.05

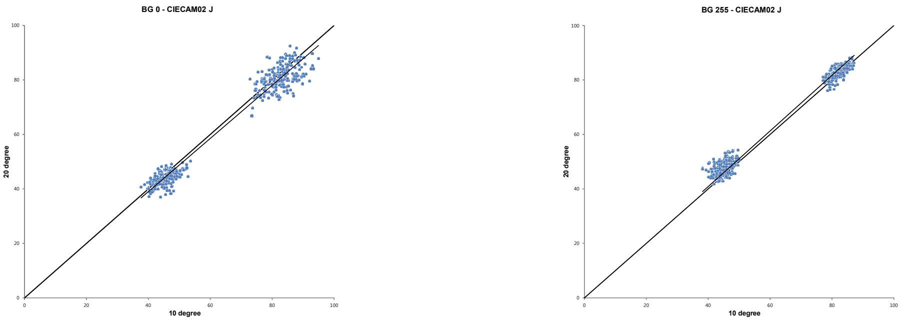

Fig. 6. Comparison of J attribute of CIECAM02 according to background brightness and stimulus size
그림 6. 배경의 밝기와 자극의 크기에 따른 CIECAM02 J 속성 비교

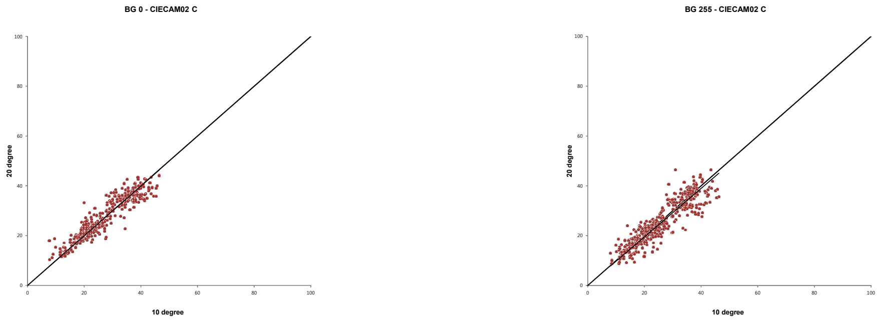

Fig. 7. Comparison of C attribute of CIECAM02 according to background brightness and stimulus size
그림 7. 배경의 밝기와 자극의 크기에 따른 CIECAM02 C 속성 비교

As seen in Table 4, J of CIECAM02 increases when the brightness of the background is dark, and C of CIECAM02 increases when the brightness of the background is bright. In other words, the darker the background, the more different the perception of the lightness between 10° and 20° stimuli, and the brighter the background, the bigger the difference in the CV values because the chroma is perceived very differently between the two stimuli.

Figure 6 and Figure 7 are graphs that show how different the perception is, particularly with regard to J and C attributes of CIECAM02, depending on the size of the stimulus and the brightness of the background. For J, which corresponds to the lightness attribute, it can be seen that when the brightness of the background is dark, the stimulus corresponding to 10° is perceived more brightly than that corresponding to 20°. Conversely, when the brightness of the background is bright, the stimulus corresponding to 20° is perceived more brightly than that corresponding to 10°. For C, which corresponds to the chroma attribute, when the brightness of the background is dark, the stimuli of 10° and 20° are perceived nearly identically, and when the brightness of the background is bright, the stimulus of 10° is perceived more colourfully than that of 20°.

Table 5. CV when the background brightness is different, for same size stimulus
표 5. 동일한 자극 크기를 대상으로 배경의 밝기가 다른 경우에서 CV

Size	J(Lightness)	C(Chroma)
10°	9.97	29.40
20°	15.00	33.77

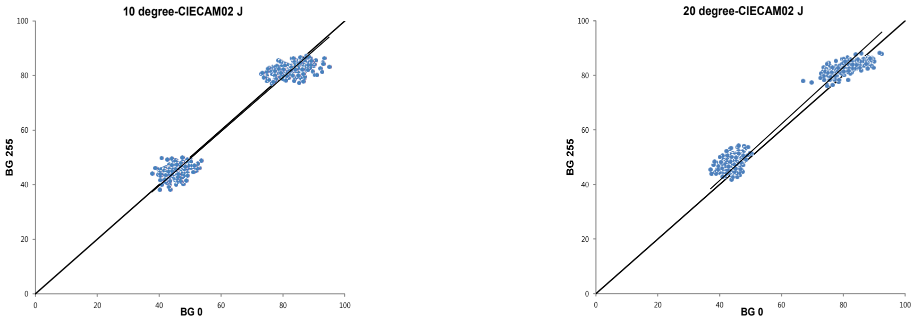

Fig. 8. Comparison of CIECAM02 J attribute when the background brightness is different, for same size stimulus
그림 8. 동일한 자극의 크기에서 배경의 밝기가 다른 경우 CIECAM02 J 속성 비교

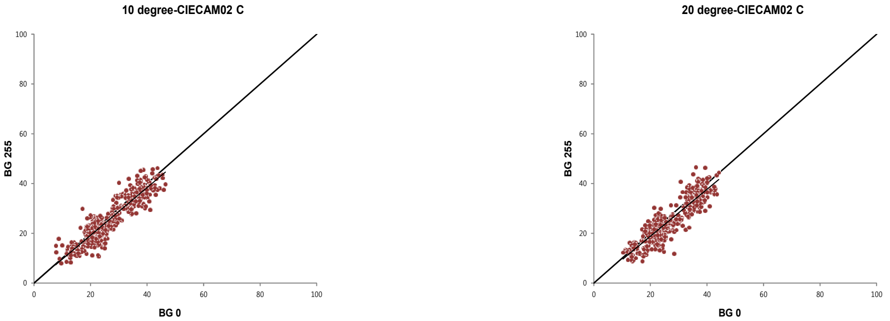

Fig. 9. Comparison of CIECAM02 C attribute when the background brightness if different, for same size stimulus
그림 9. 동일한 자극의 크기에서 배경의 밝기가 다른 경우 CIECAM02 C 속성 비교

Table 5 shows the results of analyzing, using CV, how the perception is different when the brightness of the background is different, using the same size of stimulus. The results show that when the size of the stimulus is 20° for both of the attributes J and C – that is when the size of the stimulus is large – CV increases.

Table 6. CV according to the background brightness and value and chroma combinations of test stimulus
표 6. 배경의 밝기 및 실험 자극의 value와 chroma 조합에 따른 CV

BG Lightness	Value	Chroma	J	C
0	4	4	8.01	13.70
255	4	4	12.80	28.86
0	4	8	11.60	16.93
255	4	8	18.08	31.23
0	8	4	14.42	20.51
255	8	4	2.21	30.57
0	8	8	12.90	21.72
255	8	8	2.08	29.24

It can be seen that the stimulus of size 20° is perceived to be brighter when the background is brighter, even though the size remains the same. Also, the stimulus of size 10° is perceived to be brighter when the background is dark. For attribute C, it is perceived more colourfully when the background is dark, rather than when it is bright, for both 10° and 20°.

Table 6 shows the results of analyzing J and C values in the CIECAM02 as CV according to the combinations of value and chroma, which are colour attributes of the Munsell colour stimulus used in the test, and according to the background brightness. It can be seen that when the Munsell value and chroma are both low and equal (Value4, Chroma4), or when chroma is greater than value (Value4, Chroma8), CV corresponding to J and C both increase when the background is bright. When the value is greater than

The Journal of The Institute of Internet, Broadcasting and Communication (IIBC)
Vol. 16, No. 1, pp.43-53, Feb. 29, 2016. pISSN 2289-0238, eISSN 2289-0246

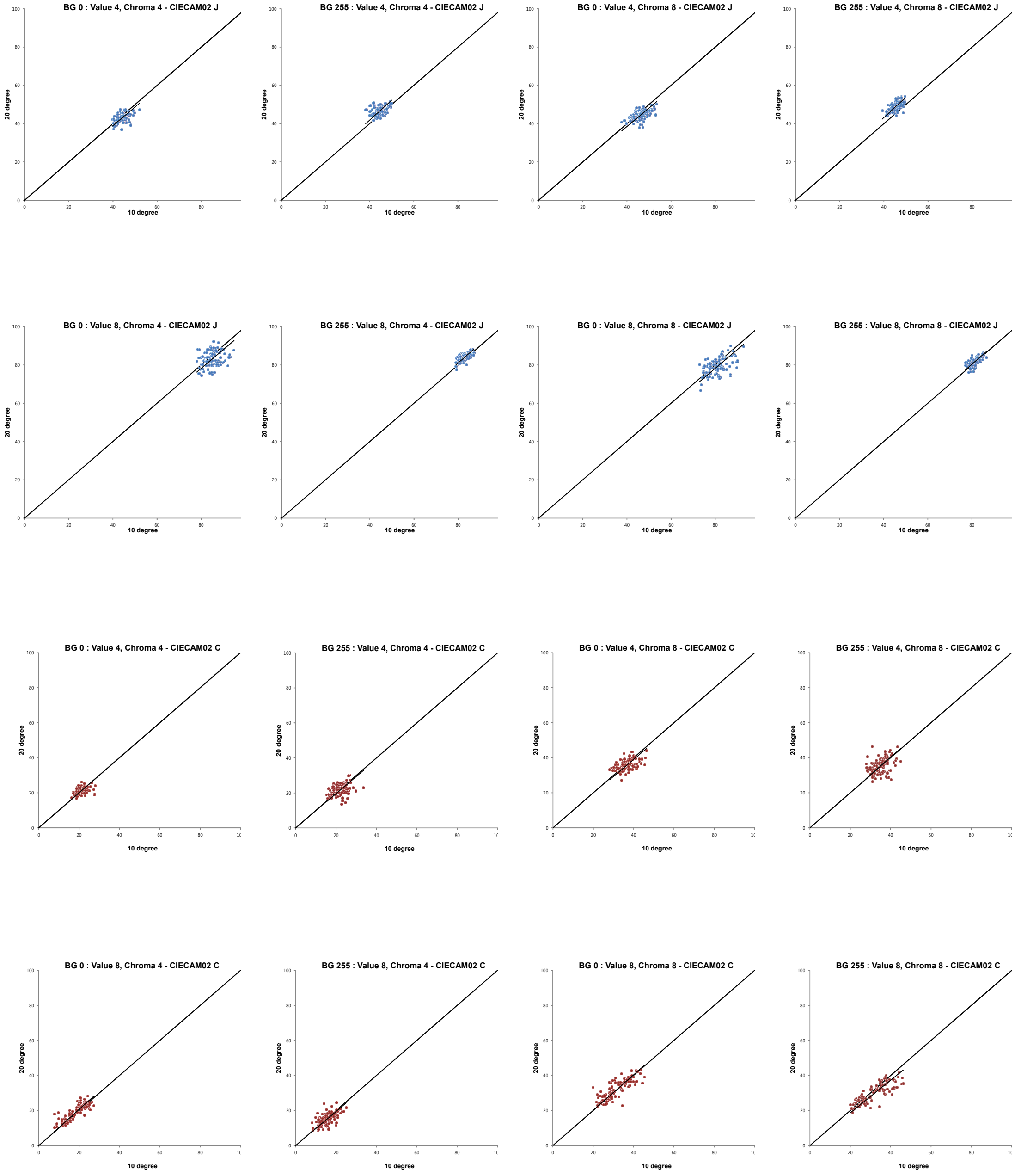

Fig. 10. Comparison of J and C attributes of CIECAM02 according to background brightness and combinations of value and chroma of test stimulus
그림 10. 배경의 밝기 및 실험 자극의 value와 chroma 조합에 따른 CIECAM02 J와 C속성 비교

chroma (Value8, Chroma4) and when value and chroma are both high and equal (Value8, Chroma8), J decreases while C increases when the background is bright.

Figure 10 is a graph that shows what kind of an effect the combinations of Munsell value and chroma have on the size of the stimulus according to background brightness. For attribute J, except for the case when both the Munsell value and chroma are high, it can be seen that the 10° stimulus is perceived more brightly than the 20° stimulus when the background is dark, but when the background is bright, the brightness is perceived similarly for both of the stimuli.

For attribute C, the Munsell value and chroma have the same values, (value 4, chroma4, and value 8, chroma 8), and when the background is bright, the 10° stimulus is perceived more colourfully than the 20° stimulus, and when the background is dark, the two stimuli are perceived similarly.

For colour combinations where the Munsell value is 4 and the chroma is 8, when the background is dark, the 10° stimulus is perceived more colourfully than the 20° stimulus, and when the background is bright, the two stimuli are perceived similarly, and for colour combinations where the Munsell value is 8 and the chroma is 4, when the background is dark, although the 20° stimulus was perceived more colourfully than the 10° stimulus, when the background was bright the 10° stimulus was perceived more colourfully than the 20° stimulus.

Ⅴ. Conclusion

This study examined the characteristics of colour perception for different sizes of stimulus according to the background brightness, in addition the size of the colour stimulus, reflecting the fact that colour vision in the peripheral retina is sensitive to brightness of the light. In addition, through a psychophysical experiment, it analyzed the tendencies involved.

Previous studies have found that as the size of the colour stimulus increases, the colours are perceived more brightly and colourfully. In contrast to this, in this study it was found that the 10° stimulus is perceived more brightly than the 20° stimulus in the colour vision in the peripheral retina when the background is dark, and when the background is bright, the 20° stimulus was perceived more brightly than the 10° stimulus. For the chroma attribute, when the background was bright the 10° stimulus was perceived more colourfully than the 20° stimulus, and when the background was dark, the two stimuli were perceived nearly identically. Also, when it comes to the combinations of Munsell value and chroma and the correlation with the background brightness, it was found that there were differences in colour perception for different sizes of stimuli according to each combination and background brightness. Overall, for stimulus with high Munsell chroma, the degree of perception of colour was different than other kinds of stimuli.

In a future study, a test will be designed to implement an algorithm so that when the size of the input image changes and as a result differences in colour perception occur according to the characteristics of the device, that it will make the necessary compensations, and a model will be implemented which reflects the colour perception characteristics according to the size of the display. In order for this, an additional test will be done where the diversity in the size of the test stimulus and the background brightness will be automatically taken into account, and the grounds for the visual characteristics involved in the perception of colour besides the size of the stimulus will be suggested.

References

[1] Wyszecki G, Stiles WS., Color Science: Concepts and Methods, Quantitative Data and Formulae, 2nd edition, 2000.

[2] Stabell B, Stabell U., Color vision in the peripherial

retina under photopic condition, Vision Res., 1982.
[3] Stabell U, Stabell B., Rod-cone color mixture: Effect of size and exposure time, J Opt Soc Am A., 1999.
[4] Nerger JL, Volbrcht VJ, Ayde CJ., Unique hue judgment as a function of test size in the fovea and at 20-deg temporal eccentricity, J Opt Soc Am A., 1995.
[5] Xiao K., Luo M. R., Li C., Cui G., Park D. S., Investigation of Color Size Effect for Color Appearance Assessment, In Color research and Application, 2011.
[6] Billger M., Evaluation of Color Reference Box as an Aid for Identification Color Appearance in Rooms, In Color research and Application, 2000.
[7] Kutas G., Bodorogi G. P., & Shanda J., Color Size Effect, In 10th Congress of the International Color Association, 2004.
[8] Andrew T. D., Eye Tracking Methodology: Theory and Practice, Springer, 2007.

저자 소개

홍 지 영(정회원)

• 2001년 : Sydney University, Multimedia Design(석사)
• 2015년 ~ 현재 : 홍익대학교 디자인·공예 색채학 박사과정, 경민대학교 광고홍보제작과 조교수
<주관심분야 : 디스플레이, 색채, 시지각, 영상처리>

박 연 선

• 전) 홍익대학교 조형대학 교수
• 사단법인 한국컬러유니버설디자인협회 회장
<주관심분야 : CUD(Colour universal design), 아동색채교육>