Effects of Hue, Saturation, and Brightness: Part 2: Attention

Nilgün Camgöz,[1]* Cengiz Yener,[2] Dilek Güvenç[3]

[1] Colour Design Research Centre, South Bank University, School of Engineering, 103 Borough Road, London SE1 0AA, UK

[2] Bilkent University, Department of Interior Architecture and Environmental Design, Faculty of Art, Design, and Architecture, 06533 Bilkent, Ankara, Turkey.

[3] Bilkent University, Department of Mathematics, Faculty of Science, 06533 Bilkent, Ankara, Turkey.

Received 3 June 2002; revised 9 November 2002; accepted 14 February 2003

Abstract: This is the second part of an experiment by Camgöz, Yener and Güvenç, which investigates attention responses for foreground-background colour relationships. One hundred and twenty three university undergraduates in Ankara, Turkey, viewed eight background colours selected from HSB colour space, on which colour squares of differing hues, saturations, and brightness's were presented. Participants were asked to show the colour square attracting the most attention on the presented background colour. Findings showed that on any background colour, colours of maximum saturation and brightness attract the most attention (67%). The yellow-green, green, and cyan range attracts the most attention (45%), followed by the red and magenta range (30%). Foreground-background colour relationships in terms of attention are also included in the findings of the study. © 2003 Wiley Periodicals, Inc. Col Res Appl, 29, 20–28, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/col.10214

Key words: color perception, color combinations, color and attention.

INTRODUCTION

Visual attention is the selective response of the eye. The main function of attention is to decide which information will be selected for high priority processing. As far as vision is concerned it is impossible for people to recognize every object in every region of their visual field at one time. The visual system accomplishes object recognition by selectively gazing on a relevant (or salient) portion of an image or a region.[1] Thus, only the information within this portion is processed, and then the visual system moves on to another relevant portion. In the context of this explanation, attention may be used in the same way as selectivity. Attention may occur in two ways: stimulus-driven or goal-directed. With stimulus-driven attention, selection is determined by the properties of the stimulus itself even if they are irrelevant to the current task. With goal-directed attention, observers' knowledge and goals determine what to select.[1] The initial goal of this research was to detect stimulus-driven attention of the viewers by recording their eye-movements. The underlying hypothesis was that certain colour squares presented would be able to provoke a strong enough stimulus so that the viewer would unintentionally look at that colour square. The eye-movement recordings of the pilot-tests showed that the viewers scanned the image that was presented briefly and then lost interest in it, staring continuously towards the screen. When they were asked the reason for staring at the center of the screen, they responded that the images presented were *only* various coloured squares of the same size on a coloured background. As they understood the pattern through a quick scan, they lost interest in it. For this reason, in the actual experiment, the research question was presented before the images were shown, and the participants made visual comparisons in order to answer the questions. Thus, the final experiment concentrated on goal-directed attention.[2]

LITERATURE REVIEW

In some studies, red was suspected to be the hue attracting the most attention.[3–6] Humphrey[4] noted that red was the

* Correspondence to: Nilgün Camgöz, Oyak 10 sitesi, 16/20, Korumah, Cayyolu 06810, Ankara, Turkey (e-mail: ncamgoz@hotmail.com)

most common colour signal in nature. He explained this with red contrasting well both with green foliage and the blue sky. Red being the colour of blood, it was thought to be able to trigger instincts of animals. However, exactly what red signaled was ambiguous. It could signal either approach (e.g. sexual display, edible food, etc.) or avoidance (e.g. aggressive behavior, poisonous substances, etc.). Humphrey[4] thought the response to red was a reflexive one. It made viewers prepare themselves to take some form of action that was defined by the context.

Kaiser[5] argued that it was unlikely to give a direct physiological response to colour, but rather that one might make certain associations to colours and that these might in turn mediate a physiological response. One explanation related to the exceptional dominance of red in attracting attention comes from Mahnke and Mahnke.[6] They explained it through the operational mechanism of the eye, where the lens of the eye has to adjust to focus on the wavelength of red light, as their natural focal point lies behind the retina. Thus, red advances, creating the illusion that red objects are closer than they actually are.

Luckiesh[3] provided one of the earliest arguments on the "retiring" and "advancing" effects of colour letters placed in the same plane. He used an apparatus with red and blue filters "of fairly high purity" with which he altered the colour of the letters "X" and "E" viewed inside wooden boxes. The participants moved the red "X" until it appeared to lie in the same plane as the blue "E." He found a lot of intersubject variability, but still in most of the cases it was necessary to move the red "X" further away in order to make it appear to be in the same plane with the blue "E."

Successive studies on the advancing property of colour found instances when blue was judged to be "nearer" than red. Pillsbury and Schaefer[7] had participants view either red neon or blue neon and argon lights. When the lights were placed equidistantly, the blue light was judged the nearer. The explanation for this "conflict" in apparent nearness of red vs. blue is explained by subsequent research that suggests brightness to be the controlling quantity for apparent distance.[8,9] The Purkinje shift, a well-known physiological phenomenon, demonstrates that blue light appears brighter than red at low luminance levels. Thus, it is to be expected that the participants of Pillsbury and Schaefer[7] judge blue light as more advancing ("nearer") than the red light at low luminance levels if brightness is the main criterion in judging "nearness."

The above mentioned studies of isolated colours focused on the process that triggered human faculties for attention. Psychological or physiological arousal or illusive apparent "nearness" might attract attention, although the reasons were not explicitly stated or discussed. The studies suggest brightness to employ the greatest role in attracting attention.

Mount *et al.*[10] conducted the first outdoor research of colour distance. It was found that each colour was judged to be closer than its nearest matching gray. Each of the hues and the grays appeared closer when viewed against a dark standard rather than the light one. They found no difference in "advancement" for one hue over another. However, as saturation of a colour was increased with respect to its background, its apparent position advanced. Colours having high brightness contrast with their background also appeared advancing. Thus, their findings suggest that increasing relative contrast by increasing an object's brightness and saturation as compared to its background makes the object appear closer. Findings of Mount *et al.*[10] are supported by the study of Oyama and Nanri.[11] Oyama and Nanri[11] had participants compare standard and variable circular shapes in all combinations of achromatic and chromatic relations on varying backgrounds under laboratory conditions. They found that the apparent size of the figure increased as its brightness increased, while the brightness of the background decreased. They found no effect of hue on apparent size.

Egusa[12] confirmed the findings of the studies above. He found an effect of hue when hemi-fields of different hues were compared for perceived depth. The green-blue difference in perceived depth was smaller than the red-green difference, with red appearing nearer. He also noted that a higher saturated colour was judged nearer when it was red or green, but there was no such effect for the blue.

In the studies above, it appears that there may be a combined effect of all attributes of colour, hue, saturation, and brightness, on attention. The effectiveness of the attributes depends on the context of presentation. Brightness seems to be the most dominant attribute. Colours having high brightness contrast with their backgrounds appear advancing. Saturation seems to be the second most important attribute of colour in judgments of "nearness." As saturation of a colour increases with respect to its background it seems closer in the visual field.

THE EXPERIMENT

This is the second part of an experiment by Camgöz *et al.*[13], which investigates attention responses for foreground-background colour relationships.

Research Hypotheses

The intention of this study is to explore effects of hue, saturation, and brightness on attracting attention with colours presented on coloured backgrounds. The following hypotheses were investigated to reveal foreground-background colour relationships:

1. Hue has an effect on attracting attention on a specific background colour.
2. Varying brightness-saturation levels of colour samples has an effect on attracting attention with specific background colours.
3. The hue of the background has an effect on attracting attention with colour samples.
4. The location of a colour sample on the computer screen has an effect on attracting attention.

FIG. 1. Experimental setup, where participants view the image sets through a computer monitor.

5. Gender of the participants has an effect on the choice of colour samples that attract attention.

Experimental Setup

Specifics of the experiment, namely the environmental factors of the experiment room, details concerning the monitor calibration, the subject group, presented image sets, and the methodology of the experiment in general are the same as in the previous studies.[2,13]

The experimental setup consisted of a computer monitor located in a windowless room, illuminated with cove lighting[2,13] (Fig. 1). Cove lighting was preferred as it excluded the possibility of glare on the monitor and created a perfect diffuse environment without any highlights that might have distracted the participants. Standard Philips TL 54 fluorescent tubes, having 6200 colour temperature (CT) and 72 colour-rendering index (CRI) was used in the coves for lighting the room.

The computer monitor was set to 1024 × 768 HiColor (16 bit), all desktop patterns were turned off, and background colour on the monitor was set to a light gray (Hue = 0, Saturation = 0, Luminance = 200; Red = 212, Green = 212, Blue = 212). Calibration details were: contrast = 240, brightness = 230, B = 140. Photoshop monitor setup was: gamma = 2.0, white point = 6500 K, phosphors = Trinitron, ambient light = medium, gamma (calibrate) = 12, white point: all RGB = 255, balance: all RGB = 0, black point: all RGB = 0. The display was spatially uniform and channel independent which was tested with chromameter measurements.

Experimental Procedure

One hundred and twenty three undergraduate students were presented image sets through a computer monitor. These were the same students that took part in the initial Camgöz *et al.*[13] experiment. Each image set consisted of a background colour selected from HSB (Hue, Saturation, Brightness) colour space and 63 colour squares of differing hues, saturations, and brightness's. Every participant viewed and answered a question for the eight different background colours.

The participant was asked: "Which colour square attracts your attention the most on the background colour on the screen?".[a] No time limits were set for making the decision. Despite the quantity of colour squares to choose from (63 colour squares for each background), none of the participants showed any difficulty or hesitation in making a selection of a single colour square.

Besides the main image set, there were three more image sets shown to the participants who answered the same question for those as well. These supplementary sets were used to investigate the effect of location of the colour squares on the choices.

All the participants were students at Bilkent University, Faculty of Art, Design, and Architecture, located in Ankara, Turkey. The majority of the participants (78%) were aged between 20–24, 81% were in the Department of Interior Architecture and Environmental Design. 41% of the participants were male, while 59% of them were female. All of the participants were from urban areas. There were no participants from small towns or rural areas with diverse cultural backgrounds. The majority of the participants were inhabitants of Ankara (76%). Participants with minor vision deficiencies were asked to take the test with their correction equipment, namely contact lenses or eyeglasses, which they wore regularly. There were no participants with severe eye or vision problems who needed to be excluded from the test. Participants were also given *Ishihara's Tests for Colour-Blindness.*[14] Anyone unable to read any of the plates shown did not participate.

The Image Sets

Adobe Photoshop 4.0[15] was used to create the entire image set. The screen area was adjusted to 1024 × 768 pixels for every image produced. All images were created in JPEG format and RGB mode. The Adobe Photoshop Colour Picker function was used to create displayed colours. Foreground and background colours were selected from a colour spectrum based on the HSB colour model within Photoshop.

The main image set consisted of eight images each with a different background colour (see Appendix A). All of the background colours had 100% saturation and 100% brightness. Thus, they were fully saturated and bright. The angle for hue was defined as an angle relative to pure red on the colour circle. Hues were selected from the standard colour circle starting with red 0°, continuing with 45° intervals, ending at magenta 315°. A list of background colours is as follows:

0° Red, 100% saturation, 100% brightness
45° Yellow, 100% saturation, 100% brightness

[a] The experimental question was asked in Turkish.

90° Yellow-green, 100% saturation, 100% brightness
135° Green, 100% saturation, 100% brightness
180° Cyan, 100% saturation, 100% brightness
225° Blue, 100% saturation, 100% brightness
270° Purple, 100% saturation, 100% brightness
315° Magenta, 100% saturation, 100% brightness

On every background colour, all the remaining hues (excluding the background hue itself) were represented in seven separate rows. Each hue row was then divided into nine columns, where the hue was represented with varying brightness and saturation levels. Explanations and examples of the images are included in Appendix A.

Three different supplementary image sets were prepared to test the location effect (see Appendix A). The research investigated whether any particular brightness-saturation range (column) or hue range (row) were attracting more attention independent of their place in an image. The first two image sets were scrolling sets. In one set, the rows (hues) were scrolling downwards and in another, the columns (brightness-saturation) were scrolling to the right. The final supplementary set was a rotating set, where the whole image was rotated clock-wise with 90° intervals (0°, 90°, 180°, 270°). All the supplementary sets were applied on four different background colours, which were paired as angular opposites of each other on the colour circle. The backgrounds used for the supplementary sets were: red 0°, cyan 180° and yellow 45°, blue 225°. Examples of the images for the supplementary sets are included in Appendix A.

DATA ANALYSIS

The statistical method Analysis of Variance (ANOVA) was applied to the collected data. The randomized complete block design is used in data analysis. The data were arranged into homogeneous groups and were compared for a number of treatments. For the main image set the homogeneous groups (blocks) were different amounts of brightness-saturation levels as presented in columns to the observer, while the treatments were differing hues as presented in rows to the observer. The hypothesis is considered as statistically significant at level of 0.05 if *P* value of the test is smaller than 0.05.

SAS[16] (Statistical Analysis System) software was used in the analysis of the collected data. Each background colour was analyzed in terms of column-row effect using ANOVA procedure; where columns represented brightness-saturation and rows represented hue. From the statistical results of the main image set, hue does not seem to have an effect on attracting attention on a specific background colour (*P* value between 0.0780–0.3443; Appendix B, Table B1). Nevertheless, supplementary image sets show that hue has an effect on attracting attention on a specific background colour (*P* value 0.0001; Appendix B, Table B2). Varying brightness-saturation levels of colour samples have an effect on attracting attention on a specific background colour (*P* value between 0.0001–0.0116; Appendix B, Tables B1 and B2). Duncan's Multiple Range Test was also applied. Pair wise comparison for each possible pair is made by this test that provides information on differences between means of each individual class, brightness-saturation and hue, in the case of individual background colours. Results from the ANOVA Procedure and Duncan's Multiple Range Test are included in Appendix B.

Background effect was also investigated by making a data structure. The statistics show a brightness-saturation effect (*P* value 0.0001; Appendix B, Table B3) and a hue effect (*P* value 0.0002; Appendix B, Table B4) on any background colour viewed. Thus, despite the changing hues of the background, certain brightness-saturation levels and certain hues attract more attention than others (brightness-saturation 100% and magenta, red, yellow-green, green and cyan; see Appendix B, Tables B3 and B4).

Location effect was investigated by analyzing responses for individual background colours that were viewed. In these images, the places of colour squares were changing on the same background colour. Responses were statistically analyzed for each brightness-saturation and hue range for every image shown. The results indicate a hue effect (*P* value 0.0001) and a brightness-saturation effect (*P* value 0.0001), despite the changing locations of hues and brightness-saturation levels on the computer screen (see Camgöz[2]).

Gender effect was investigated for the main image set by applying ANOVA procedure. The analysis revealed no gender effect on attention choices (*P* values between 0.2473–0.5417) (see Camgöz[2]).

DISCUSSION

Analyzing the data required interpretation of all the *P* values obtained from the main and supplementary sets (Appendix B). Sometimes the data from the main image set were not significantly differentiating any colour attributes (hue, saturation, brightness), but significant groupings were attained from supplementary sets. As the colours shown for every image and the subject group were the same, all statistics were interpreted as a whole. The tables and figures indicating the colours for attracting attention contain statistically significant attributes obtained from Duncan's Analysis. If there were no differentiated attribute from Duncan's Analysis, but the attribute was still statistically significant, attributes of highest percentage from response distribution data for that image were included. All the percentages given in the text are obtained from the main image set.

The data gathered and analyzed in this study show that brightness-saturation levels are more important in attracting attention than specific hues viewed on varying background colours. In every background colour, brightness-saturation 100% was chosen as attracting the most attention (67%). This range contains colour squares that are most saturated and brightest on the images shown. This finding, to some extent, supports previous studies of Taylor and Sumner[8] and Johns and Sumner[9], which stated brightness as the control-

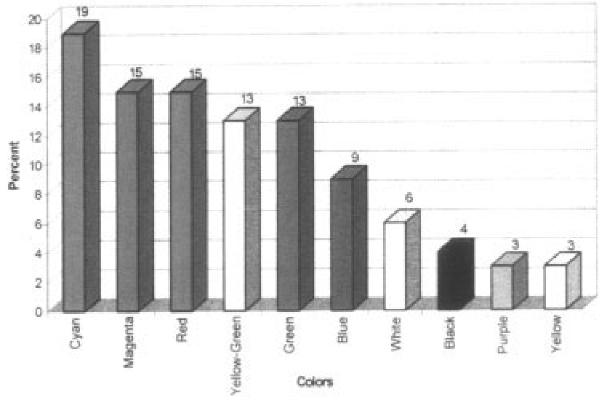


FIG. 2. Percent-scale of attracting attention for hues on any background colour.

ling factor for attracting attention. These studies did not give much importance to saturation, which was found to be another determinant factor in this study.

Egusa[12] suggested that an increase in saturation would promote "nearness," and consequently attract attention. This statement was verified by the findings of the experiment. The Mount *et al.*[10] study emphasized the importance of brightness and saturation contrast on apparent advancement of a colour. The condition of this contrast relationship was set as increasing the brightness and saturation of the foreground object compared to its background. Due to the design of the experiment, the results of this study do not provide support for contrast relationships. All the background colours viewed were of maximum saturation and of maximum brightness. There was no option for the participant to choose a foreground colour square which was "more saturated" and "brighter" than the background. Thus, the contrast relationship suggested by Mount *et al.*[10] has not been tested within the scope of this study.

The participants chose the brightness-saturation 100% range colour squares on brightness-saturation 100% background colours. Thus, the brightness and saturation levels of the background and the foreground were selected to be the same. It should be noted that this study used the HSB system. The variations between this system and the more commonly used CIEL*a*b* system is discussed in Appendix C, Table C1.

In general, cyan (19%), magenta (15%), red (15%), yellow-green (13%), and green (13%) attract attention on any background colour (see Fig. 2). Thus, the red, magenta range (30%) and the yellow-green, green, cyan range (45%) on the colour circle attract the most attention. Luckiesh[3], Mahnke and Mahnke[6], and Egusa[12] emphasized that red was apparently "nearer" or "advancing" in the visual field. Data from the experiment demonstrated that red, magenta range competed with yellow-green, green, cyan range in attracting attention. There is no evidence in the present research that suggests red wavelengths to be more capable of attracting attention than other hues. Blue (9%), the non-colours of white (6%) and black (4%), yellow (3%) and purple (3%) attract attention the least on any background colour viewed (see Fig. 2).

Cyan attracts the most attention on red (33%) and yellow (41%) backgrounds. Magenta (30%) and red (17%) attract attention on cyan background. Red attracts attention on blue background (35%). No statistically significant hues stood out for the background colours of yellow-green, green, purple, and magenta in terms of attention. However, the following can be stated. Magenta and cyan may attract attention on yellow-green (29% m., 30% c.), and green (28% m., 26% c.) background colours. Red, yellow-green, and green may attract attention on purple (26% r., 21% yg., 21% g.) background. Yellow-green and green may attract attention on magenta (46% yg., 29% g.) background (see Table 1).

Concerning the initial hypotheses, the experimental results show that:

TABLE 1. Hues that attract attention on specified backgrounds.

Background Color	Stimulus Color
Red	Cyan (33%)
Yellow	Cyan (41%)
Yellow-Green*	Cyan (30%), Magenta (29%)
Green*	Magenta (28%), Cyan (26%)
Cyan	Magenta (30%), Red (17%)
Blue	Red (35%)
Purple*	Red (26%), Yellow-Green (21%), Green (21%)
Magenta*	Yellow-Green (46%), Green (29%)

* No statistically significant hues were differentiated for these background colours, thus tendencies from response distributions have been included.

1. Hue effect on attention seems to be of secondary importance, and requires viewing of a specific background colour more than once to come to a visual decision.
2. Varying brightness-saturation levels of colour samples have an effect on attracting attention on a specific background colour.
3. Despite the changing hues of the background, some brightness-saturation levels and some hues attract more attention.
4. Despite changing the locations of colour samples on the computer screen, some brightness-saturation levels and some hues attract more attention than others.
5. Gender of the participants does not have an effect on the choice of colour samples that attract attention.

CONCLUSION

The experimental results showed that brightness and saturation levels are more important than hue component in attracting attention. On every background colour, the coloured squares having maximum saturation and maximum brightness were found to attract the most attention. It should be noted that all the background colours also had maximum saturation and maximum brightness. Previous studies suggest maximum contrast to be of primary importance, with the condition that the stimulus should be brighter and more saturated than the background. In this study, background and foreground colour squares chosen by participants had the same saturation and brightness levels, both being the maximum. Thus, there is no contrast of either brightness or saturation (see also Appendix C, Table C1). This finding does not contradict previous studies since the contrast suggested in these studies required higher saturation and higher brightness level of the foreground stimulus. As the perceived colour squares could not have higher brightness or saturation levels than their background, the ones that had the same (which is the maximum level) brightness and saturation level with the background were chosen. This perceptual elimination of brightness and saturation attributes of colour enabled study of the hue effect on various backgrounds in terms of attention.

The red, magenta portion of the visible spectrum attracted significant attention regardless of the background colour (30%). However, the yellow-green, green, cyan portion of the visible spectrum attracted more attention with 45% of the responses. Blue (9%), purple (3%), and yellow (3%) rated significantly lower in attracting attention on any background colour.

There is no data from past experimental research on colour combinations that specify foreground-background colour relationships. Thus, research findings of this dual relationship could not be compared with previous studies. The analysis of individual backgrounds is tabulated in Table 1 in terms of hues that attract the most attention on specified background colours.

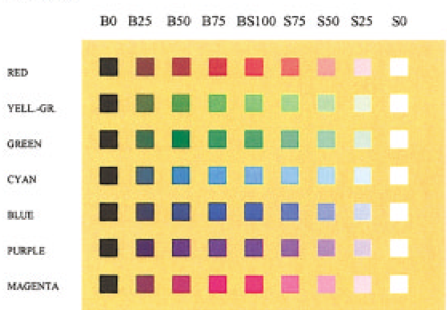
Studies on colour combinations always deal with simultaneous colour contrast. Simultaneous colour contrast is the visual effect that occurs when two different colours are placed side by side, where both will exhibit changes of appearance. Chevreul[17] and Rood[18] have reported the influence of the background colour on the colour of a patch. The effect of simultaneous colour contrast definitely influenced the participants' judgments as it is a natural mechanism of the eye (Appendix C, Table C2). Colours in our everyday life are never viewed in isolation and this study attempts to contribute to attention responses for colours in combination. Thus, the effects of simultaneous contrast were included in designing the experiment, which might explain why a significant effect of hue was found in the supplementary image sets and not for the main image set. The background of the supplementary image sets was the same and therefore the effect of simultaneous colour contrast was the same for all foreground colours.

The statistical analyses show that location and gender have no significant effect on the choices made for attention in this experiment.

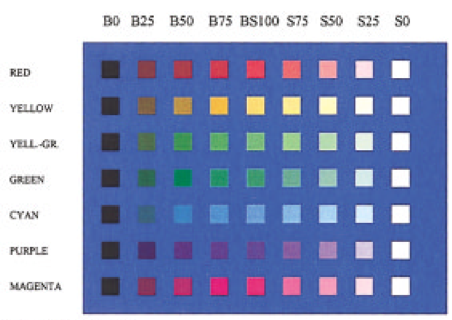
The results of the study may be used in computer applications like computer graphics, web page design, etc., and in luminous signage applications. Moreover, the study contributes to the available data on the subject in an attempt to broaden the understanding of colour combinations.

APPENDIX A: TWO EXAMPLES FROM EACH IMAGE SET

The Main Image Set: Places of Brightness-Saturation levels and Hues remained the same while background colours were changing.

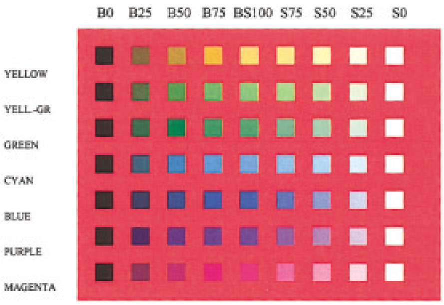


Yellow Background

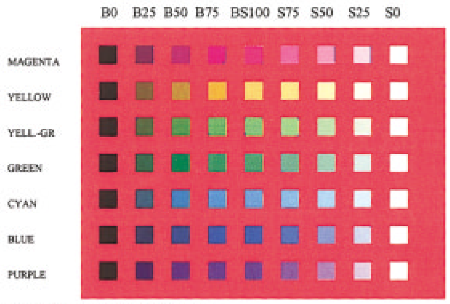


Blue Background

The First Supplementary Image Set (scrolling down): Places of Hues were changing in each image, moving towards one row below. For example, yellow in the first row in the first image would move to the second row in the second image, etc.

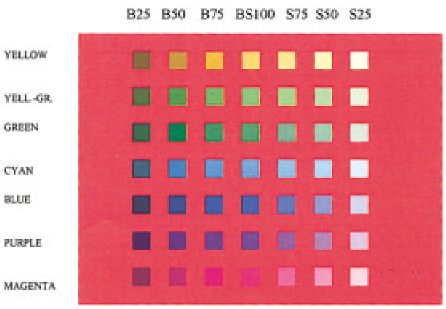


Red Background/ 1st Image

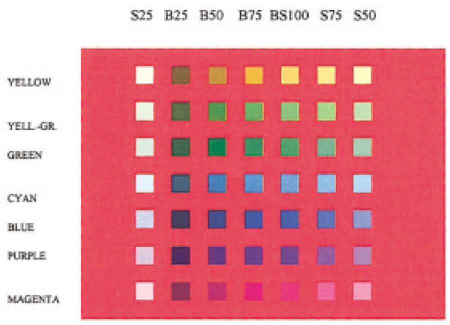


Red Background/ 2nd Image

The Second Supplementary Image Set (Scrolling to the right): Places of Brightness-Saturation levels were changing in each image, moving towards one column to the right. B25 in the first column in the first image would move to the second column in the second image, etc.

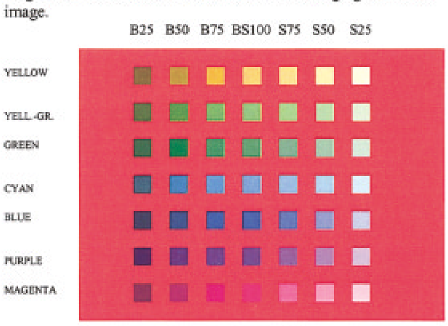


Red Background/ 1st Image

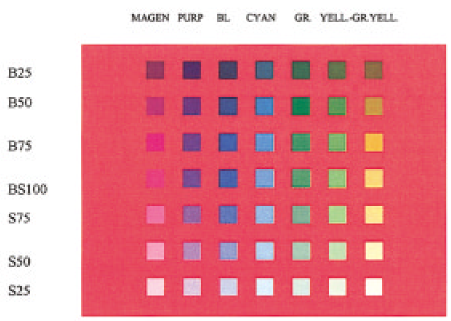


Red Background/ 2nd Image

The Third Supplementary Image Set (Rotating): Images were rotated 90° clock-wise, where places of both Brightness-Saturation levels and Hues were changing with each image.



Red Background/ 1st Image



Red Background/ 2nd Image

APPENDIX B: *P* VALUES AND DUNCAN GROUPINGS

TABLE B1. Brightness-Saturation and Hue effect.

Background colours	*P* value for Brightness-Saturation	Duncan grouping for Brightness-Saturation	*P* value for Hue	Duncan grouping for Hue
Red	**0.0001**	BS100	0.2454	None different
Yellow	**0.0001**	BS100	0.1821	None different
Yellow-Green	**0.0001**	BS100	0.0780	None different
Green	**0.0001**	BS100	0.1210	None different
Cyan	**0.0005**	BS100	0.3443	None different
Blue	**0.0001**	BS100	0.3382	None different
Purple	**0.0001**	BS100	0.2085	None different
Magenta	**0.0116**	BS100	0.3343	None different

TABLE B2. Brightness-Saturation and Hue effect (supplementary image sets).

Background colours	*P* value for Brightness-Saturation	Duncan grouping for Brightness-Saturation	*P* value for Hue	Duncan grouping for Hue
Red	**0.0001**	BS100	**0.0001**	Cyan
Yellow	**0.0001**	BS100	**0.0001**	Cyan
Cyan	**0.0001**	BS100	**0.0001**	Red
Blue	**0.0001**	BS100	**0.0001**	Red

APPENDIX C: PERCEIVING COLOURS IN COMBINATION

The HSB (Hue, Saturation, Brightness) system has been used in this study, as it is the most convenient terminology for designers outside the field of colour science. Agoston[19] refers to the HSB system as useful when the diverse psychological effects commonly experienced in colour vision and the broad subject of colour appearance is considered (pg.187). On the other hand the CIEL**a***b** system has been adopted generally for the specification of colour and has been widely used in industrial applications. The difference between the two systems is in the way they determine the hue and saturation coefficients for the colours (Agoston[19], pg.185). In the HSB case, the chromatic response functions are used, whereas the CIE uses colour-matching functions (Agoston[19], pg. 185).

This article uses the saturation and brightness values in the HSB colour space, which derives from chromatic response functions. If the CIEL**a***b** system derived from colour-matching functions was used the saturation and brightness values would change. While the brightness values of HSB colour space are the same, their CIE L^* values (which are related to brightness) are different, ranging from 37 (blue) to 91 (cyan) (see Table C1). A further study designed with CIEL**a***b** system would be of interest to compare its findings with this study.

Simultaneous colour contrast also plays an important role in this study. Simultaneous colour contrast not only affects perceived hue, but also perceived saturation that results from colour induction. Agoston[19] describes the phenomena with the network structure of the retina: "Although the receptor cones may be tiny enough to differentiate fine detail in an image, each is connected to nerve cells among which there are multiple interconnections. In this way, light that falls on one point of the retina can affect signals from receptors in an area that surrounds that point." (pg. 199; see Table C2).

TABLE B3. Brightness-Saturation and Background effect.

	P value for Brightness-Saturation	Duncan grouping for Brightness-Saturation
On any background colour	**0.0001**	BS100

TABLE B4. Hue and Background effect.

	P value for Hue	Duncan grouping for Hue
On any background colour	**0.0002**	Cyan, Magenta, Red, Yellow-Green, Green

TABLE C1. HSB values and the corresponding CIE $L^*a^*b^*$ values of colours used in the study.[a]

Background colours	Hue (0 to 360)	Saturation (0 to 100)	Brightness (0 to 100)	L^* (0 to 100)	a^* (−128 to 127)	b^* (−128 to 127)
Red	0	100	100	54	81	70
Yellow	45	100	100	82	15	83
Yellow-Green	90	100	100	90	−61	84
Green	135	100	100	88	−78	70
Cyan	180	100	100	91	−51	−15
Blue	225	100	100	37	46	−99
Purple	270	100	100	39	75	−96
Magenta	315	100	100	57	88	−29

[a] Derived from the Adobe Photoshop colour picker.

TABLE C2. Simultaneous colour contrast.[a]

Patch	Patch colour in isolation (aperture colour)	Patch colour influenced by red background
1	Yellow	Greenish yellow
2	Purple	Blue
3	Blue	Greenish blue
4	Blue green	Blue green

[a] Influence of a red background on the perceived colour of a patch (Agoston[19], pg. 200–201)

1. Hsieh Y-H. Spatiotemporal characteristics of interaction between exogenous and endogenous orienting of visual attention [Diss.]: Ohio State U; 1999.
2. Camgöz N. Effects of hue, saturation, and brightness on attention and preference [Diss]. Ankara: Bilkent University; 2000. 246 p.
3. Luckiesh M. On “retiring” and “advancing” colors. Am J Psychol 1918;29:182–186.
4. Humphrey N. The colour currency of nature. In: Mikellides B, editor. Colour for architecture. London: Macmillan; 1976. p 95–98.
5. Kaiser PK. Physiological response to color: A critical review. Color Res Appl 1984;9(1):29–36.
6. Mahnke FH, Mahnke RH. Color and light in man-made environments. New York: Van Nostrand Reinhold; 1987.
7. Pillsbury WB, Schaefer BR. A note on advancing-retreating colors. Am J Psychol 1937;49:126–130.
8. Taylor IL, Sumner FC. Actual brightness and distance of individual colors when their apparent distance is held constant. J Psych 1945;19: 79–85.
9. Johns EH, Sumner FC. Relation of the brightness differences of colors to their apparent distances. J Psychol 1948;26:25–29.
10. Mount GE, Case HW, Sanderson JW, Brenner R. Distance judgment of colored objects. J Gen Psychol 1956;55:207–214.
11. Oyama T, Nanri R. The effects of hue and brightness on the size perception. Japan Psychol Res 1960;2(1):13–20.
12. Egusa H. Effects of brightness, hue and saturation on perceived depth between adjacent regions in the visual field. Perception 1983;12(2): 167–175.
13. Camgöz N, Yener C, Güvenç D. Effects of hue, saturation, and brightness on preference. Color Res Appl 2002;27(3):199–207.
14. Ishihara S. Ishihara’s tests for colour-blindness. Tokyo: Kanehara Shuppan Co; 1975.
15. Adobe Systems I. Adobe PhotoShop 4.0 [CD-ROM]. 4.0; 1996.
16. SAS. Sas [Release 6.03 ed]. 6.12. Cary.
17. Chevreul M. The principles of harmony and contrast of colors and their applications in the arts. New York: Van Nostrand Reinhold; 1967.
18. Rood O. Modern chromatics: Students’ textbook of color with applications to art and industry. New York: Van Nostrand Reinhold; 1973.
19. Agoston G. Color theory and its application in art and design. Berlin: Springer-Verlag; 1987.