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How Koreans understand colorfulness, chroma, vividness and depth

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Abstract

In this study, the relationships between chae-do, the commonly used Korean terminology to describe chromatic attributes, CIE definition for colorfulness, Munsell definition for chroma, Berns' definition for CIELAB based vividness and depth are investigated. Although only the definitions were presented, without corresponding terminologies, the observers' responses showed that chae-do is understood very similarly to the definitions of CIE colorfulness and Munsell chroma. Responses for the definitions of vividness and depth also showed high correlation with Berns' CIELAB based vividness and depth predictions, which shows that definitions were well understood. No correlations were found between the definition of CIE colorfulness and the definition of vividness, which shows that the definition of vividness is understood differently to the definition of colorfulness. Comparing the response with color appearance model predictions, the responses showed good correlation with the predictions. Especially, colorfulness definition responses showed the highest coefficient correlation with CIELAB-based Berns' depth prediction, implying the possibility of colorfulness predictor modification for better prediction. The findings can be further investigated to observers from other non-English speaking countries and collect meaningful cross-cultural color appearance data.

Introduction

Lightness, chroma and hue are the color appearance attributes used in color appearance assessment experiments [1]. Each of these three color appearance attributes are one-dimensional scale and are considered independent of one another [2]. Using the attributes, color appearance models such as CIECAM02 are developed mainly based magnitude estimation experiments [3].

Terminologies used by colorists in the related industry are not parallel with the lightness or chroma plane [4][5]. Berns introduced new attributes extending CIELAB, which follows the diagonal of the lightness-chroma plane, vividness (V*ab) and depth (D*ab) [6].

When the observers are given the definition of color appearance attributes, the meaning should be understood clearly without confusion. However, it is well known that chromatic attributes are difficult to evaluate for untrained observers, unlike hue and lightness [7][8]. The definitions are available in English which may be understood differently for non-English speaking observers. Also, there can be another definition easier to understand.

The relationships between the current definitions for the chromatic attributes and the Korean observers' responses on these attributes are investigated. One terminology and four definitions were asked for 25 NCS color patches, applying magnitude estimation to Korean observers, those who are not color professionals. The terminology included the 'chae-do', which is the Korean word used indistinctively for chroma and colorfulness.

Methods

Collecting definitions

Definitions related to chromatic attributes were collected from previous studies. One terminology and four definitions were selected, which are Korean terminology 'chae-do', definitions of CIE colorfulness, Munsell chroma, Berns vividness and Berns depth. Chae-do is the Korean terminology commonly used to represent the chromatic attributes, but whether it is close to chroma or colorfulness is unconfirmed. The definitions presented to the observers are as follows:

- an attribute of a visual perception according to which the perceived colour of an area appears to be more or less chromatic (CIE colorfulness, [9])
- an attribute of colour used to indicate the degree of departure of the colour from a neutral colour of the same lightness (Munsell Chroma, [10])
- an attribute of colour used to indicate the degree of departure of the colour from a neutral black colour (Berns Vividness, [6])
- an attribute of colour used to indicate the degree of departure of the colour from a neutral white colour (Berns Depth, [6])

Note that no definition was given for chae-do to evaluate the concept of chae-do already known by the observers from experience and past education. The correlation between the terminology chae-do and the definitions of CIE colorfulness and Munsell chroma are compared to investigate the understanding of naïve observers. Berns definitions of vividness and depth involved the notion of distance. These definitions are selected to evaluate the possibility of easier color appearance attribute for the observers.

Experimental setting

In the darkroom, viewing booth (Judge II, X-Rite) was placed on a worktable. The viewing booth had D65 lighting with luminance of 242.91 cd/m^2 for 0500-N patch. The observers sat in front of the viewing booth with 60 cm distance. The booth was warmed-up for 15 minutes prior to the observation for stability. As shown in Figure 1, the color patches were placed inside the viewing booth with the reference color patch on the left and the test color patch on the right.

Procedure

The observers assessed the degree of a particular attribute on how the test color appeared, applying method of magnitude estimation. This method asks the observer to assign the magnitude of perception numerically [1]. In this study, the test color patch was compared to the reference color patch.

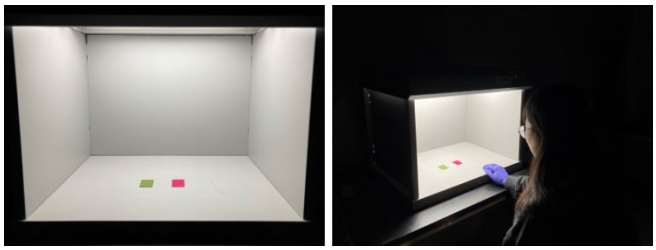

Figure 1. Experimental setting of the viewing booth and color patches

The observer first read through the definition and organized what they understood. The terminology chae-do was presented, then assessed for the four definitions as presented in the previous section. Only the definitions were presented to the observer, without the according terminologies. For each terminology or definition, the observer evaluated each test patch in relation to the reference patch, which was set as 50. When responding the magnitude of perception in numbers, no upper limit was given but zero was set as the lower limit. After evaluating one test color patch, next color patch was presented with the same reference. The evaluation was repeated for 25 test color patches, consisting of 20 colors and 5 colors. Five colors were chosen at random for repetition to test response consistency.

Selection of 20 color patches were made from the Natural Color System (NCS) color chart. Four hues were selected and from each hue, five patches were chosen. The color patches were measured with a spectroradiometer (CS-2000, Konica Minolta) from the same distance as the observer. Reference white was selected as 0500-N patch and CIELAB was calculated using this reference white. The reference color patch was selected as 4040-G50Y color patch that was not used as the test color having the average lightness and chroma of the test colors. The CIELAB distribution of the 20 colors shown in Figure 2.

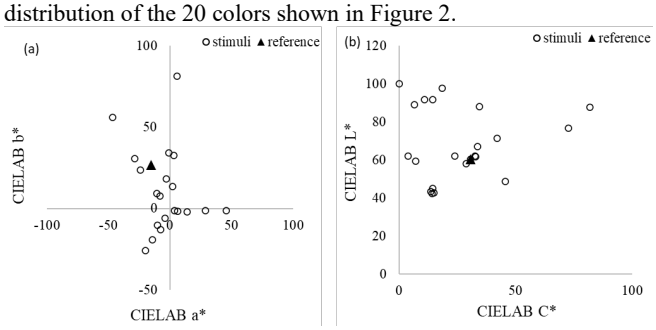

Figure 2. 20 color patches on (a) CIELAB a-b* and (b) CIELAB C*-L**

Fifteen Korean undergraduate and graduate students participated for the experiment (7 males and 8 females, aged 23-25, normal color vision). Observers were familiar with reading and understanding in English as the definitions were presented in English.

Results and Discussions

Observers' performance

The average repeatability was calculated from the five repeated color patches from each definition. The average repeatability is shown in Table 1, which is the average coefficient of variation (CV) values for repeated patches. Low CV values imply that the repeatability was good.

Table 1: CV values for observer repeatability

	Chae-do	CIE Colorful-ness	Munsell Chroma	Berns Vivid-ness	Berns Depth
CV (%)	14.41	10.18	10.59	9.15	11.44

Table 2 shows the observers reproducibility - CV values between the subject responses and the average for each definition. The CV value was the lowest for vividness, which means that the definition of vividness was interpreted to a similar degree of understanding among observers.

Table 2: CV values of observer reproducibility

	Chae-do	CIE Colorful-ness	Munsell Chroma	Berns Vivid-ness	Berns Depth
CV (%)	30.30	30.47	30.24	25.49	27.26

Relationship between observers' responses and definitions

The correlation coefficients for the observers' responses are high for chae-do vs CIE definition of colorfulness (r=0.988), chae-do vs Munsell definition of chroma (r=0.984), CIE definition of colorfulness vs Munsell definition of chroma (r=0.984). Figure 3 shows the relationships and the correlation coefficients are summarized in Table 3. Dotted line is the 45-degree line for Figure 3 (a), (b) and (c). The results imply that the terminology chae-do is already well understood similarly to the definition of colorfulness and definition of chroma. For further data analysis, responses for chae-do and responses for definition of CIE colorfulness and Munsell chroma are averaged into one terminology and will be represented as colorfulness for the model testing section of this study. As shown in Table 3, the current definitions of chromatic attributes showed low correlation with definition of Berns vividness, which implies that chromatic attributes are understood as different attributes with the definitions of Berns vividness.

The responses for the definition of vividness and depth showed negative correlation (r=-0.838). As shown in Figure 3 (d) and Table 3, definitions of vividness and depth had no correlation with terminology chae-do, definition of CIE colorfulness and definition of Munsell chroma. Dotted line in Figure 3 (d) is the -45-degree line.

Table 3: Correlation coefficient for definition responses

r	CIE Colorful-ness	Munsell Chroma	Vividness	Depth
Chae-do	**0.988**	**0.984**	-0.045	0.539
CIE Colorful-ness		**0.984**	-0.056	0.546
Munsell Chroma			-0.134	0.625
Vividness				**-0.838**

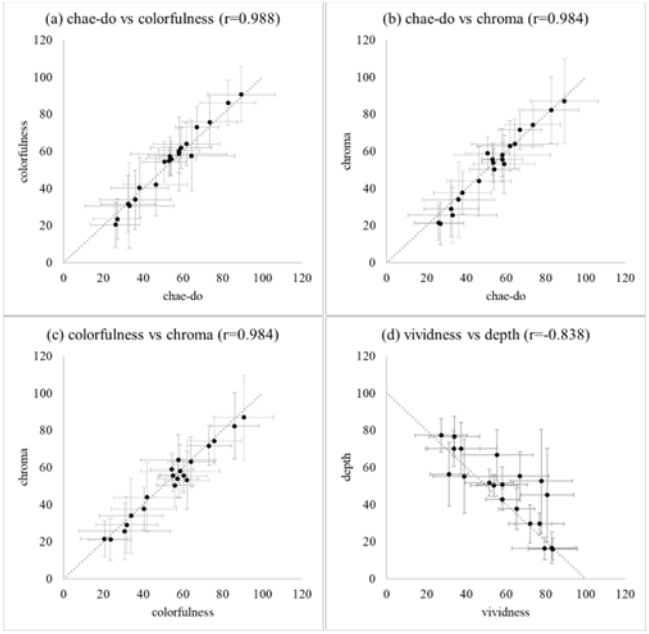

Figure 3. Observers' responses to (a) terminology chae-do vs definition of CIE colorfulness (b) terminology chae-do vs definition of Munsell chroma (c) definition of CIE colorfulness vs definition of Munsell chroma (d) definition of Berns vividness vs definition of Berns depth

Color appearance model test: colorfulness

Responses for colorfulness definitions are compared with the predictions of color appearance models using correlation coefficients as summarized in Table 4. As in Figure 4, colorfulness definition responses showed high correlation with CIECAM02 C (r=0.847). The dotted lines are the trend lines.

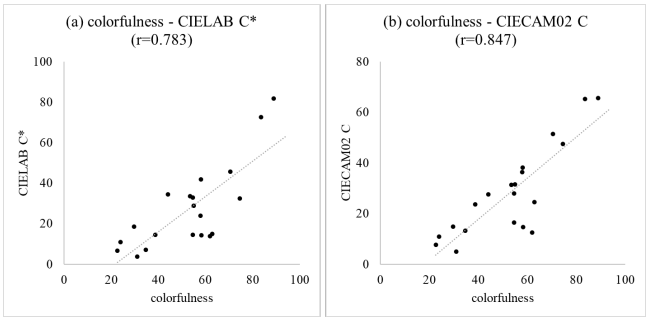

Figure 4. Colorfulness definition responses compared with (a) CIELAB C predictions and (b) CIECAM02 C predictions*

To note, colorfulness definition responses showed the highest coefficient correlation with CIELAB-based Berns' depth prediction (r=0.916) as in Figure 5. CIECAM02 based vividness and depth predictions are compared, which can be calculated by applying CIECAM02 J and C to Berns' vividness and depth prediction equations [6]. It implies the possibility of colorfulness predictor modification for better performance. Colorfulness prediction equation may include lightness parameter to have better correlation with the visual results.

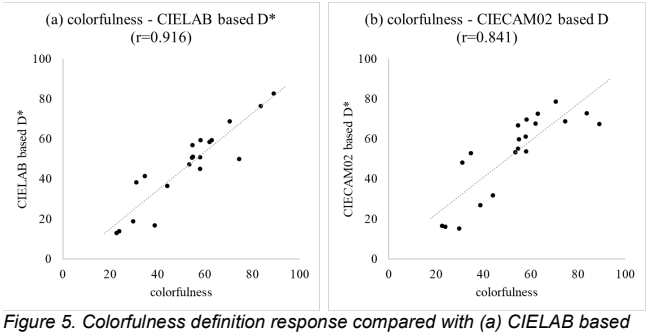

Figure 5. Colorfulness definition response compared with (a) CIELAB based D predictions and (b) CIECAM02 based D predictions*

Table 4: Correlation coefficient of definition of colorfulness, vividness and depth responses and model predictions of CIELAB and CIECAM02

	CIELAB		
r	CIELAB C*	CIELAB based V*	CIELAB based D*
Colorful-ness	**0.783**	0.018	**0.916**
Vividness	0.422	**0.914**	-0.351
Depth	0.029	-0.742	**0.740**
	CIECAM02		
r	CIECAM02 C	CIECAM02 based V	CIECAM02 based D
Colorful-ness	**0.847**	-0.042	**0.841**
Vividness	0.366	**0.953**	-0.564
Depth	0.120	**-0.790**	**0.886**

Color appearance model test: vividness and depth

Responses for the definitions of vividness and depth are compared with CIELAB based Berns' model predictions. Observers' response for vividness showed high coefficient correlation with CIECAM02 based V prediction (r=0.953) as well as for depth responses with CIECAM02 based D (r=0.886) prediction as shown in Figure 6, Figure 7 and Table 4.

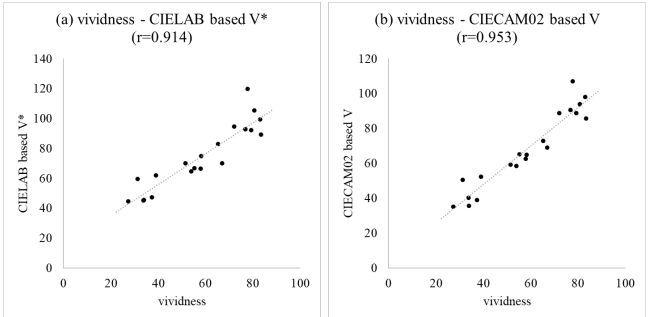

Figure 6. Vividness definition responses compared with (a) CIELAB based V predictions and (b) CIECAM02 based V predictions*

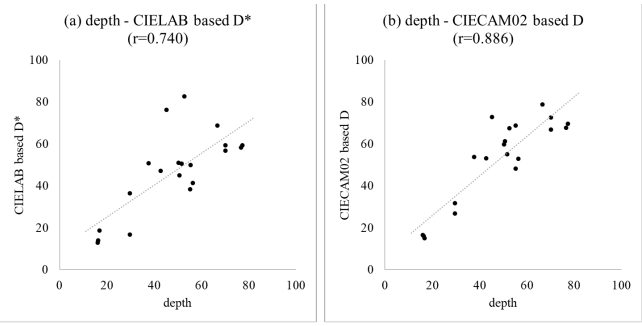

Figure 7. Depth definition responses compared with (a) CIELAB based D predictions (b) CIECAM02 based D predictions*

Conclusion and Future Work

In this paper, the relationships of the terminology chae-do with the CIE definition of colorfulness, Munsell definition of chroma, Berns' definition of vividness and depth are investigated. Chae-do is the Korean word used to describe the chromatic attribute and used indistinctively for chroma and colorfulness.

Magnitude estimation experiments were conducted using 25 NCS color patches with 15 observers. The experimental results showed that the understanding of the definition for colorfulness and chroma were similar to what is already known for the terminology, chae-do. This implies that the understanding of the literal translation of the English definitions for colorfulness and chroma are well understood by Korean observers. Notably, the response for the definition of colorfulness showed high correlation with Berns' CIELAB based depth prediction, which hints the possibility of colorfulness predictor modification for performance improvement.

Furthermore, the responses for definitions of vividness and depth showed high correlation with CIELAB and CIECAM02 based vividness and depth predictions, which implies that the definitions are easily and accurately understood by the observers. There were no correlations between the responses for the definition of colorfulness and the definition of vividness, which shows that the two definitions are understood differently.

The study evaluates whether collecting color appearance data with English definitions of the terminologies is useful to the non-English speaking, non-professional observers. The findings can be further investigated to observers from other non-English speaking countries and collect meaningful cross-cultural color appearance data.

Acknowledgement

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