Temporal transition enhances the consonance of color arrangements

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Abstract

We found a similarity between the effect of temporal chord transition in music and temporal color transition in visual perception. Human visual impressions between a color arrangement and a temporal transition from a modified arrangement to the original arrangement were compared in experiments with sensory tests. The experimental results showed that the consonance of color arrangements can be enhanced by a "pivoted" transition, in which some appearance parameters like hues and color tones are preserved, from a dissonant arrangement in comparison with a static presentation of the original arrangement. The results suggest that an enhancement effect of consonance similar to resolution of chords in music exists in a higher order mechanism of human color vision.

Introduction

In music theory, *resolution* is one of the most important structures of music pieces [1, 2]. The resolution means a temporal progress from dissonance to consonance. The resolution of chords in the context of tonal music means a progress from a more dissonant chord to a more consonant one, and it induces deeper satisfaction to listeners than the single use of the latter consonant chord.

We assume that there is an analogy between the temporal transition of chords in musical perception and the temporal transition of color arrangements in visual perception. A temporal transition of colors from a dissonant arrangement to a consonant one may cause more satisfaction than the single appearance of the latter consonant arrangement.

Some researches have studied visual effects of temporal color transitions [3, 4]. They mainly investigate visually smooth process of transitions. However, no one investigated the difference between static and dynamic color arrangements in human visual impressions.

We conducted an experiment in which static color arrangements and temporal transitions were presented to observers. In the temporal transition conditions, a color arrangement of which one color was replaced from the original was presented, and then the replaced color was restituted gradually. The results showed statistically significant differences between the impressions to the static arrangements and those to the transitional ones. The results suggest that a "pivoted" transition, in which some appearance parameters like hues and color tones are preserved as a pivot, induces a consonance enhancement similarly to a smooth chord transition inducing resolution from dissonance to consonance in music.

Methods

Color samples and PCCS

We prepared five pairs of color arrangements. Each pair contains the followings:

- Arrangement S (static): A tricolor arrangement, which is composed of a typical arrangement in harmony in the sense of graphic design.
- Arrangement T (transitional): One of the three colors of the arrangement S is replaced with another color, and the modified color gradually changes back to the original one during the observation. The modified color gradually disappears, and simultaneously the original color gradually appears, in the transition process.

The five pairs prepared for the experiment are shown in Figs. 4-8. The color arrangements are shown in (a) of each figures. The right one is the arrangement S, and the left one is the modified arrangement where the color with $*$ was replaced, and the left one gradually changes back to the right one in the arrangement T. The color circle and squares in (b) indicate the hues of colors used in the samples. The arrow indicates the transition in the arrangement T.

These color sets are arranged based on the Practical Color Co-ordinate System (PCCS) [5], which is a color system developed by Nihon Sikiken Co., Japan. It is organized based on Ostwald color system and adapted to perceptual characteristics of Japanese people.

The main concept of the color expression in the PCCS is the categorization of colors according to "tone," which is the combination of lightness and saturation. Different impressions of the same hue are categorized by the concept of tone. Figure 1 shows the tones in the PCCS. Twelve typical tones are indicated by a combination of lightness and saturation, and the hue circle is assigned to each tone.

Figure 2 shows the hue circle of the PCCS. It arranges 24 or 12 hues, and the intervals between hues are controlled to be identical in human impressions. The four psychological primaries, indicated by the symbol $\bigcirc$, and their complements are assigned in the circle at first, and four more hues are interpolated to control the intervals to be identical. Twelve more hues are interpolated into the 12-hue circle to generate the 24-hue circle. The symbols $\blacktriangleright$ and $\triangleright$ indicate the CMY and RGB primaries, respectively. The parameters for lightness and saturation are also assigned to indicate perceptually constant intervals, as shown in Fig. 3.

The parameter settings of the colors employed in the experiments are shown in Table 1. The parameters are shown in RGB

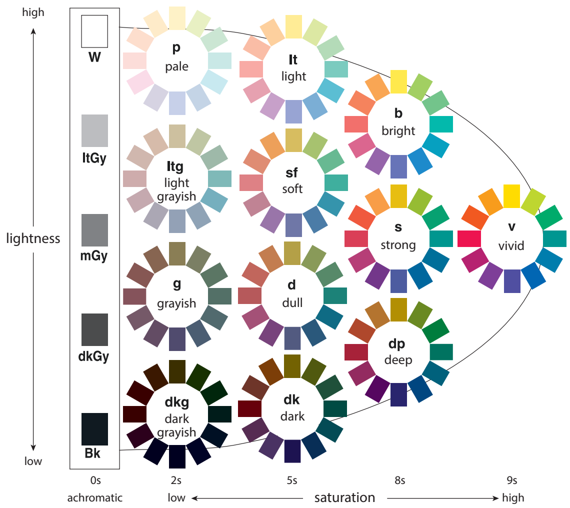

Figure 1. Tones in the PCCS [5].

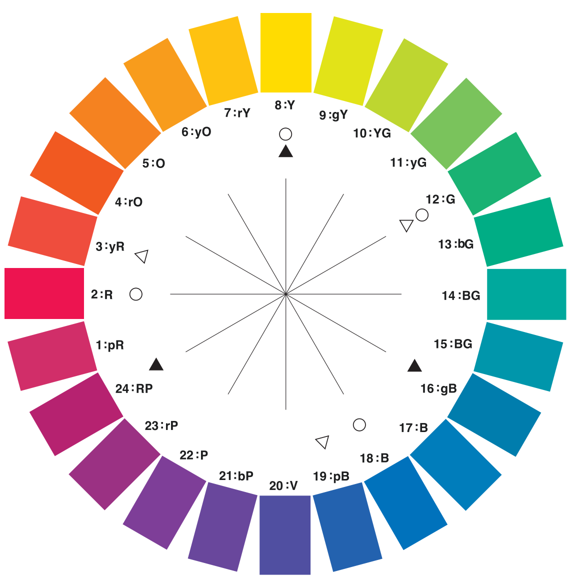

Figure 2. Hue circle in the PCCS [5].

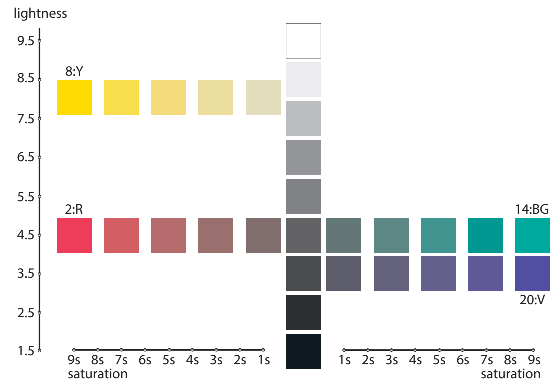

Figure 3. Lightness and saturation parameters in the PCCS [5].

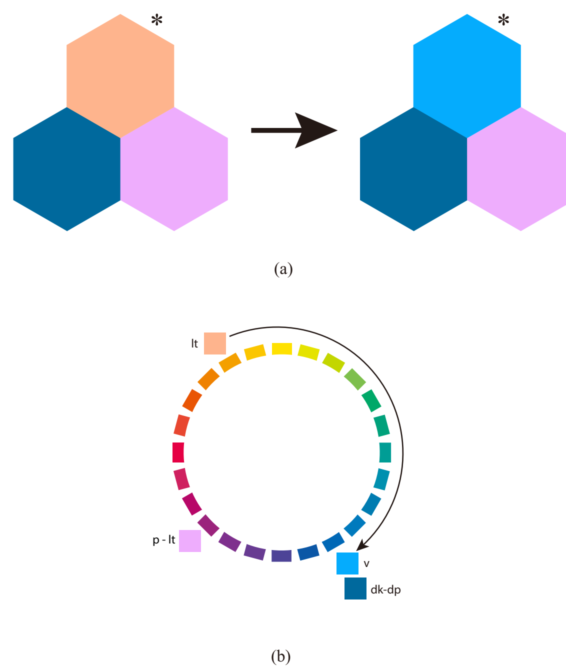

Figure 4. Color arrangement 1S/1T.

and HSV spaces, where R,G, and B parameters are in the range of [0, 255], H parameters are in the range of [0, 360) degrees, and S and V parameters are in the range of [0, 100] percent. The upper row in the settings of each arrangement shows the parameters of the colors which are unchanged in the transitional arrangement. The lower row shows the parameters of the colors changed in the transition. These parameters are controlled to select one of the color examples in the PCCS on the employed displays.

The arrangement 1S contains, as shown in Fig. 4, two colors of the same hue but different saturation to organize consonance. One of these two colors is replaced with the complementary color of the other in the arrangement 1T. The arrangement 2S is composed of three colors of similar saturation and lightness, and the hues are displaced from each other. One of the three colors is replaced with a color of the same hue but higher saturation in the arrangement 2T. The arrangements 3S/3T contain achromatic colors. One of the grays is replaced in the arrangement 3T, and the contrast becomes higher in the transition. The arrangement 4S is a typical consonant arrangement composed of two colors of complimentary hues and the same saturations. The arrangement 4T has the transition process of the hue and lightness of the modified color which moves back to the complementary position. The arrangement 5S shows a contrast between the one color on the top and the two colors at the bottom. The hue of the color on the top is modified in the arrangement 5T.

Procedure

The color samples are displayed on a LCD and presented to the observer. The sizes of the diagonal line of the LCDs used in the experiment are 118 cm and 128 cm, and the distances between

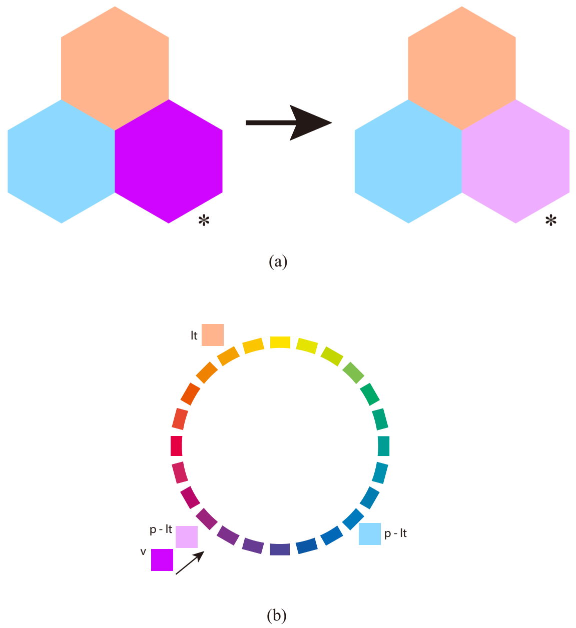

Figure 5. *Color arrangement 2S/2T.*

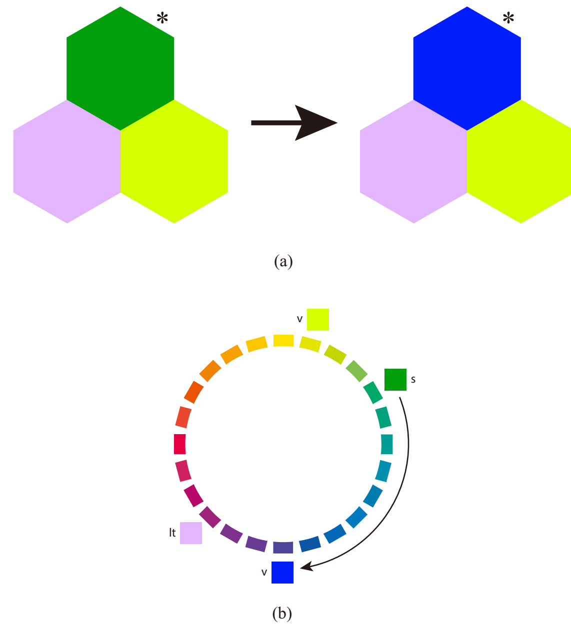

Figure 7. *Color arrangement 4S/4T.*

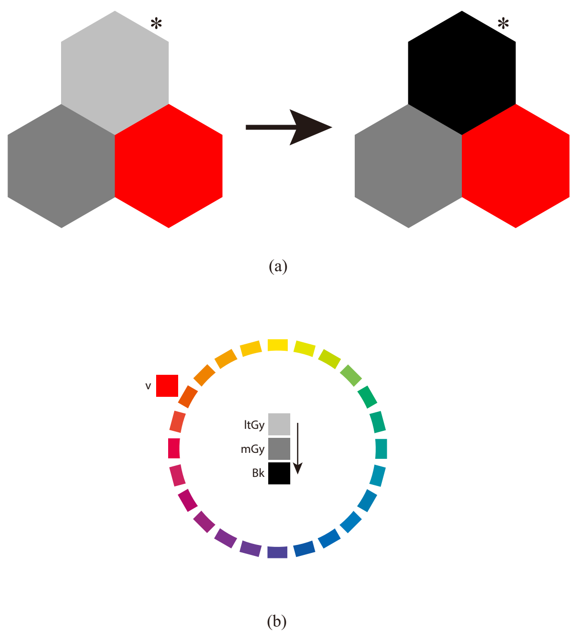

Figure 6. *Color arrangement 3S/3T.*

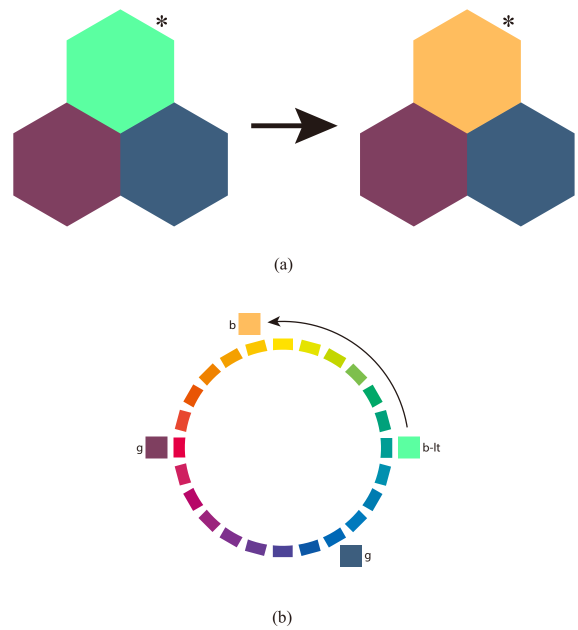

Figure 8. *Color arrangement 5S/5T.*

the LCD and the observer are 265 cm and 288 cm, respectively. The distances are controlled to make the viewing angles identical for different LCDs. The presenting order of the 10 arrangements in total is randomized, regardless of being the static ones or transitional ones, in the presenting process.

It is not told to the observers that some of the color samples are transitional at the beginning of the experiment. The presenting process is as follows:

1. The observer is requested to watch the LCD.
2. One of the color samples appears. The static sample is presented for 10 seconds and disappears. The transitional sample is also presented for 10 seconds. In this case, the transition starts at the moment when the sample appears. The transition completes in 5 seconds, and the sample is stably presented for 5 more seconds and then disappears.
3. The observer is requested to answer the sensory test.
4. The steps 1-3 are repeated for all of the 10 samples.

Table 1. Color parameter settings.

Arrangements 1S/1T							
	R	G	B		R	G	B
	0	105	157		238	173	254
	255	180	142		5	172	253
	H	S	V		H	S	V
	200	100	62		288	32	100
	20	44	100		200	98	99
Arrangements 2S/2T							
	R	G	B		R	G	B
	255	180	142		141	216	254
	208	5	255		238	173	254
	H	S	V		H	S	V
	20	44	100		200	44	99
	288	98	100		288	31	99
Arrangements 3S/3T							
	R	G	B		R	G	B
	127	127	127		254	0	0
	191	191	191		0	0	0
	H	S	V		H	S	V
	0	0	49		0	100	99
	0	0	74		0	0	0
Arrangements 4S/4T							
	R	G	B		R	G	B
	227	181	253		211	255	0
	0	159	11		0	29	251
	H	S	V		H	S	V
	278	28	99		70	100	100
	124	100	62		233	100	98
Arrangements 5S/5T							
	R	G	B		R	G	B
	127	63	96		61	94	126
	91	255	161		255	189	94
	H	S	V		H	S	V
	329	50	49		209	51	49
	145	64	100		35	63	100

Table 2. Item pairs in the sensory test.

−	+
calm	lively
poor color arrangement	good color arrangement
artificial	natural
inelegant	elegant
usual	strange
hard	soft

The sensory test is answered using a 7-step scale from −3 to 3, and the item pairs are shown in Table 2. The observers were 36 Japanese university students, and the sensory test was written in Japanese. The items shown in Table 2 have been translated into English.

Table 3. Average scores of the sensory test.

−	+	1S/1T	2S/2T	3S/3T	4S/4T	5S/5T
cal.	liv.	0.139	−0.250	−0.417	−0.528	0.500
poor	good	−0.750	0.750	0.472	−0.667	0.583
art.	nat.	−0.778	0.528	−0.194	−0.250	0.194
inel.	el.	−0.694	0.611	0.083	−0.056	0.444
usu.	str.	0.944	0.194	−0.500	0.139	−0.722
hard	soft	−1.083	0.528	−0.167	−0.306	0.556

Table 4. Double-sided p-values.

−	+	1S/1T	2S/2T	3S/3T	4S/4T	5S/5T
cal.	liv.	0.571	0.378	0.153	0.045	0.141
poor	good	0.017	**0.002**	0.167	**0.002**	0.045
art.	nat.	0.038	0.057	0.450	0.409	0.455
inel.	el.	0.036	0.022	0.083	0.840	0.147
usu.	str.	**0.004**	0.539	0.133	0.599	0.022
hard	soft	**0.001**	0.011	0.422	0.270	0.029

Results and discussion

Table 3 shows the averages of the observer differences of the scores in the sensory tests between one static arrangement (e.g. the arrangement "1S") and its transitional counterpart (e.g. "1T"). The positive value indicates that the score in the case of the transitional arrangement is higher in average. The cells with positive values are painted in blue, while those with negative values are in red.

The double-sided paired t-test was applied to find whether each observer difference was considered statistically significant or not. The p-values are shown in Table 4. The p-values smaller than 0.05 are indicated in green, and those smaller than 0.01 are in boldface.

We focus on the "poor color arrangement"-"good color arrangement" pair in the sensory test. The results are statistically significant at 5% significant level for the arrangement pairs except 3S/3T. It indicates that the transition of the colors has an effect in human impression in these cases.

The transitional arrangements are evaluated positive, i.e. better than the static counterparts, in average in the cases of the arrangement pairs 2S/2T and 5S/5T, while negative in the cases of 1S/1T and 4S/4T. The transition in the arrangement 2T preserves the hue of changing colors. The arrangement 2S has three colors of the similar tones in the sense of the PCCS, "p-lt" and "lt," , while the transition in 2T starts from an unbalanced tone arrangement. The transition in the arrangement 5T almost preserves the tone of changing colors, and only the hue is modified. These transitions preserve one of the appearance parameters, in the sense of tone, of the arrangements. It indicates that "pivoted" transitions, in which some appearance parameter like the color tone is preserved as a pivot, induce positive effect, similarly to smooth chord transitions in resolution from dissonance to consonance in music.

The transitional arrangements are evaluated negative, i.e. worse than the static counterparts, in average in the cases of 1S/1T and 4S/4T. It may be because they have no pivot characteristics, and the starting arrangements of the transitions 1T and 4T are composed of complementary colors and also rather consonant. About the arrangement pairs 3S/3T, the transition has almost no effect. Since the arrangement 3S is visually vivid because of its high contrast, it is estimated that the impression is determined by this arrangement also in the transitional arrangement 3T.

Conclusions

We have presented experimental results that show effects of temporal transition of color arrangements to human impressions. The results indicate that the consonance of color arrangements can be enhanced by a "pivoted" transition, in which some appearance parameters like hues and color tones are preserved, from a dissonant arrangement in comparison with a static presentation of the original arrangement. The results suggest that an enhancement effect of consonance similar to resolution of chords in music exists in a higher order mechanism of human color vision.

The next step to this preliminary results is controlling the color parameters more accurately and precisely independently to display environments, and finding a theory of systematically designing temporal transition of colors to emphasize satisfactory impressions. This theory will realize "composition" of dynamic color arrangements in the same sense of music composition with harmonics theory.

Acknowledgments

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