Chapter #12

THE RELATIONSHIP BETWEEN COLOR PREFERENCE AND REACTION TIME

Shengai Jin & Yasuhiro Kawabata
Graduate School of Letters, Hokkaido University, Sapporo, Japan

ABSTRACT
This study investigated the relationship between preference for color combinations and reaction times for their evaluation among participants aged between 20 and 30 years. In this study, we found that: 1. among color combinations, light tones were generally preferred over vivid, dark tones; the most preferred color combination was Y & G (including yellow-green and green-yellow), whereas the most disliked color combination was R & G (including red-green and green-red). 2. The evaluation of color preference for the more popular light tones had a weak, negative correlation with reaction time, whereas the evaluation of color preference for the disliked dark tones had a positive correlation with reaction time. Thus, preferred colors such as the Y & G combination and the single- color blue were associated with shorter reaction times than disliked colors such as the combination of R & G or the single color yellow. 3. The reaction time for single-colors was generally longer than for the color combinations.

Keywords: preference, color combinations, reaction time.

1. INTRODUCTION

Humans' color preferences are influenced by group-level factors such as trends, cultures, or regions, as well as more individualized characteristics such as gender or personality. Thus, color preferences are not always constant among individuals, and many do not remain constant in their preference for a specific color. According to 'Evaluation for color's impression on the website (Copyright © 2009-2018 https://iro-color.com) which conducts questionnaires on color desirability every year in Japan, "cold" colors (blue and green) are popular among monochromes and disliked colors were loose by people. However, we come in contact with many colors in our daily lives, and people often experience varying combinations of multiple colors as well as monochromes, which impress people differently. The semantic differential (SD) method of measuring color preferences present subjects with sets of opposing adjectives to capture their opinions, whereby feelings are expressed between contrasting terms and factor analysis is used to discern individuals' generalized predilections from the resulting adjective combinations. A number of studies have used SD techniques to assess individuals' positive and negative perceptions of color-combinations, and researchers have reported finding a strong correlation between harmony and color combination preferences, whereby predilections are determined based on impressions of "color harmony" (Maki, Ide, & Kato, 2016; Naya, Mori, Tsujimoto, Ikeda, & Namba, 1966; Oyama & Miyata, 2012).

In recent years, researchers have also analyzed color preferences based on more objective indicators such as reaction time and eye movement. Several studies examining reaction times have indicated that an inverse ratio exists between a preference and reaction time, such that people take less time to express their likings than when no preference exists

(Aaker, Bagozzi, Carman, & MacLachlan, 1980; Haaijer, Kamakura, & Wedel, 2000; Klein & Yadav, 1989). Similar results were reported in studies by Dashiell (1937) and Shipley, Coffin, and Hadsell (1945), which demonstrated that reaction times tend to be brief in cases when participants have a strong preference (either positive or negative) for a given color, but also proposed that people generally examine the things they like more closely than other items. Lee, Tang, and Tsai (2005) collected objective color preference data using eye tracking, and the results showed that the number and duration of gazes were noticeably larger when presented with preferred colors. If we assume that reaction time and gaze time are analogous, then we can posit that fixation time will be longer when choosing liked things than those that are disliked or not associated with a preference.

A number of studies investigating relationships between reaction time and preferences among single colors have found a strong negative correlation between preference of single colors and reaction time, such that reaction times were shorter for favorite single colors than for those that were less preferred (Hovancik, 2000). However, to-date, no studies have examined the relationship between people's reaction times and preference ratings for bichrome images or compared such relationships between perceptions of monochromes and bichrome images. As mentioned above, there is a strong correlation between individuals' reaction times and their preference determinations regarding objects, and such determinations appear to be made based on perceptions of the harmony of color combinations. However, this factor is not applicable in the case of monochromes, and it would be useful to compare differences in reaction time between ratings of monochromes and color combinations. It is expected that such comparisons would find differences in reaction times between judgements of monochromes and bichrome images, such that it might be more difficult (and thus take longer time) to determine preferences among the latter.

As mentioned above, there is a strong correlation between individuals' reaction times and their preferences for objects, and such determinations appear likely to be made based on perceptions of the harmony of color combinations. However, this element is not applicable in the case of monochromes, and it would be useful to compare differences in reaction time between ratings for monochrome and color combinations.

Therefore, this study aimed to extend previous studies by clarifying if there is a stronger negative correlation between color preference ratings and reaction time when people evaluate color combinations Therefore, this study aimed to extend previous studies by clarifying if there is a stronger negative correlation between color preference and reaction time when people evaluate color combinations than when they assess monochromes. A related question for analysis is whether differences in light vs. dark tones impact reaction times and/or preferences, as well as whether the distance between colors might influence the speed and character of such reactions

2. METHOD

2.1. Participants

A total of 21 students from Hokkaido University participated in this study (7 male, 14 female; M_{age} = 23, SD = ±4.6). According to the preliminary survey, none of the participants had any visual or color vision deficiencies, and this was confirmed when respondents took the Ishihara Color Vision prior to the onset of the experiment.

2.2. Stimuli

We selected seven colors from the PCCS (Practical Color Coordinate System developed by the Japan Color Research Institute.): red (R); orange (O); yellow (Y); blue (B); cyan (C); green (G) and medium-gray. Medium-gray was used as a background "plate" filled screen for a total of 12 color combinations comprised of pairings between the first six colors as R-G (red is on the left and green is on the right). Medium-gray was used as a background for a total of 12 color combinations comprised of 11 pairings between the first six colors to form R-G, R-C, R-B, Y-G, Y-C, Y-B, G-R, G-O, G-Y, C-R, C-O, C-Y. Each color in the pairings is listed according to its appearance on the gray plate, such that in some cases, the same color pairs were used in reverse order. Each color-combination was divided into different tone systems ranging from light to vivid to dark (as selected from the PCCS) and according to varying degrees of distance between the color-combinations as shown in Figure 1.

Figure 1.
Examples of color stimuli pairings and spacing.

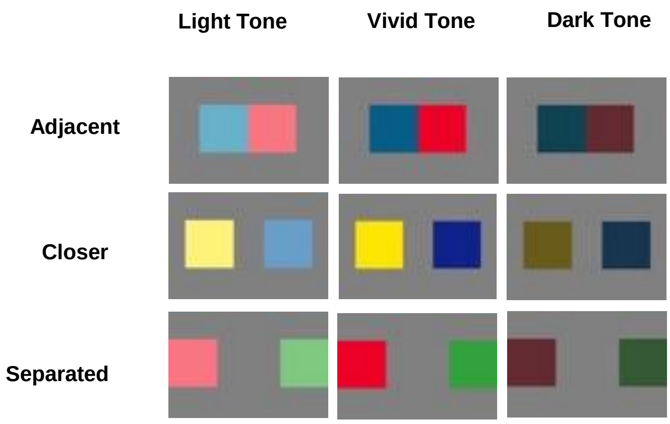


Table 1 shows the RGB 256 gradation of each color stimulus and Yxy chromaticity coordinates (Iis from the independent values of luminance(Y) and chrominance(xy)) measured by the Konika Minolta CS-100A color luminance meter. The three degrees of distance between the color-combinations in Figure 1 were denoted as "adjacent," "closer," and "separated," respectively, such that "adjacent" described no distance, "closer" denoted an interval of 3.5cm (4.56° of visual angle) and "separated" indicated an interval of 7.5cm (9.74° of visual angle) distance. Each monochrome of the color combinations was positioned such that it appeared once on the left side of the plate and once on the right side and the dimensions of the color patches were 5.5×5.5cm. The color stimuli were displayed with a resolution of 82×1200 pixels. All of the data for participants' reaction times were calculated using Superlab software.

Table 1.
Stimuli on RGB256 & Yxy(CIE).

		R	G	B	x	y	Y(cd/m^2)
Light Tone	RED	250	116	130	0.454	0.315	34.4
	ORANGE	253	180	108	0.439	0.402	54.6
	YELLOW	255	242	123	0.395	0.444	86.2
	GREEN	127	201	126	0.308	0.441	47.8
	CYAN	103	178	202	0.242	0.293	39.0
	BLUE	103	159	202	0.237	0.264	31.9
Vivid Tone	RED	238	0	38	0.620	0.319	18.3
	ORANGE	255	127	0	0.544	0.406	36.4
	YELLOW	255	230	0	0.438	0.490	77.9
	GREEN	51	162	61	0.298	0.529	26.9
	CYAN	5	93	135	0.197	0.227	9.6
	BLUE	15	33	139	0.163	0.092	3.1
Dark Tone	RED	99	42	49	0.450	0.313	4.5
	ORANGE	108	73	25	0.466	0.427	8.0
	YELLOW	105	91	24	0.429	0.465	10.6
	GREEN	52	89	52	0.307	0.445	8.1
	CYAN	14	66	81	0.217	0.275	4.6
	BLUE	22	52	79	0.212	0.228	3.2
Background	Medium-Gray	159	160	160	0.308	0.330	79.5

2.3. Procedure

The participants were seated facing the screen and the experimenter asked them to remain still and maintain the same position. They were seated approximately 44cm away from the screen (1920 × 1080pxl, color temperature 7500K). When each stimulus was presented, the participants had to consider their preferences concerning the color combinations while adhering to the instruction to accurately estimate each stimulus as fast as possible. The assessments of single colors or color combinations were scored on an 11-point Likert scale on which 0 represented the worst, and 10 represented the best. Each participant evaluated each color patch using same method. The reaction time was recorded from the time that the stimulus appeared until the participant pressed the corresponding button to complete their rating.

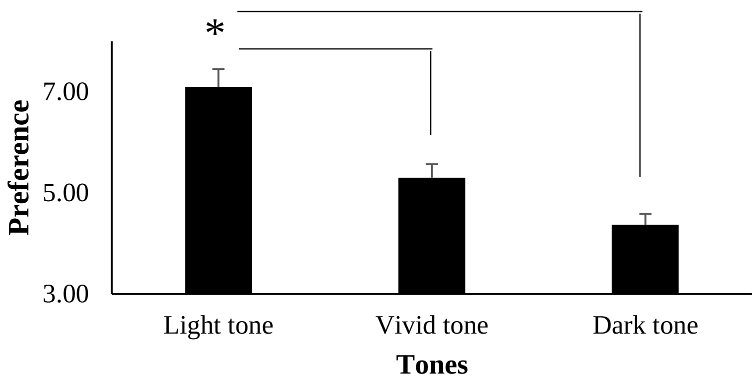
3. RESULTS

3.1. Color preferences

First, to investigate the gender differences in the preference for color combination, the two-factor analysis of variance between participants was used. The results show that there was no significant difference in the interaction between gender and color perceptions; however, the main effect was significantly different at each factor ($F(11, 2328) = 1.44$, $p < .15$; $F(1, 2328) = 6.75$, $p < .05$; $F(11,2328) = 5.38$, $p < .0001$), and males' ratings were higher than females' ratings for color combinations (Males: $M_{preference} = 5.85$, $SD = \pm 3.0$; Females: $M_{preference} = 5.50$, $SD = \pm 3.1$) as well as for monochromes females (Males: $M_{preference} = 5.81$, $SD = \pm 2.4$; Females: $M_{preference} = 5.08$, $SD = \pm 2.7$). There were no differences in color preferences between participants in this experiment.

Secondly, the three-factor within-subjects analysis of variance was used to analyze preferences concerning color combinations, whereby the three variables were tone, distance, and hue. The results indicated an interaction between tone and color-combinations ($F(22,440) = 5.52$, $p < .05$), a main effect of tone ($F(2,40) = 9.68$, $p < .01$), and no main effect of interval distance ($F(22,440) = 0.05$, ns), nor any interaction with interval distance. Light tones were significantly preferred over other tones ($t(1,40) = 4.33$、$p<.0001$; $t(1,40) = 2.85$、$p<.05$, see Figure 2), and the preference for combinations of yellow and green (including yellow-green and green-yellow) and yellow and cyan combinations was significantly greater than combinations of red and green or red and cyan ($t(1,220) = 7.01$, $p <.0001$; $t(1,220) = 3.86$, $p <.001$; $t(1,220) = 7.95$, $p <.0001$; $t(1,220) = 7.79$, $P <.0001$)(see the right vertical axis in Figure 4). Among single colors, there were significant differences between tone preferences, whereby light tones were preferred over dark tones ($F(2,40)=6.67$、$p<.01$; $t(1,40) = 3.64$, $P <.005$). There was also a significant difference in the main effect of single color preferences ($F(5,100)=4.99$、$p<.01$;), such that blue, cyan, and green were better liked than yellow, red, and orange (see the right vertical axis in Figure 5).

Figure 2.
Preferences for color combinations in different tone.

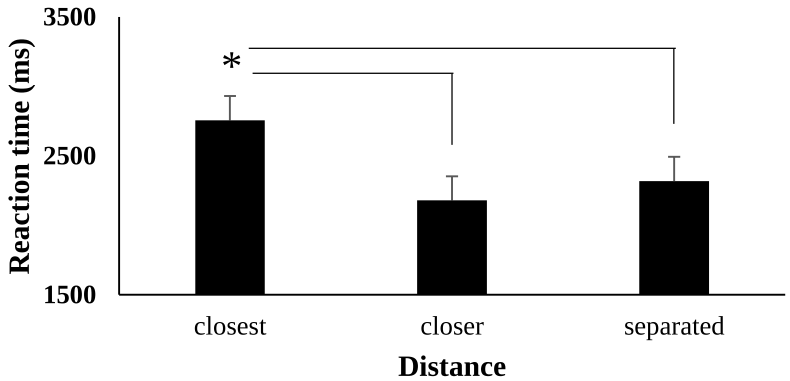


Note. * p<.05

3.2. Reaction times

Reaction time was measured from the moment of presentation of each color combination until the participant pressed the button and the numerical value was recorded. Three factors of combinations of tone, interval distance, and color (12) were used to analyze the within-subjects variance, and significant differences were found in the interactions between distance and color combination and in the main effect of distance ($F(22,440) =2.20$, $p<.005$; $F(2,40) =18.76$, $p<.00001$). According to the simple main effect test of color combinations for each interval, the reaction time for “adjacent” colors was significantly longer for R-G than for any combinations other than G-R and G-O, and the reaction time associated with G-R was significantly longer than those for all of the other combinations. Among the reaction times for “closer” colors, the time to rate R-G was significantly longer than R-B, Y-C, or G-Y, and among the times for “separated” colors, ratings for R-G took significantly longer than all the others. In determining the main effect of the distance between colors, the reaction time for the adjacent colors was longer than those for both the closer- and separated color ratings (t (1,40) =5.87, $p<.00001$; t (1,40) =4.45, $p<.0001$), and no difference was found between the reaction times of the latter two distance categories (see Figure 3). This result provides a mixed answer to the research question of whether the interval of distance between the two components of color combinations would impact reaction times, such that some distance between colors facilitates preference determination more than when they are immediately adjacent; however, the experiment did not identify any "optimal" distance for hastening judgements of bichrome images.

Figure 3.
Reaction times for color ratings based on distance.



3.3. Relationship between color preferences and reaction time

Based on the above results, we understood that participants' color preferences were influenced by tone, whereas their reaction times were affected by the distance between the components of the color combinations. Therefore, to analyze the correlation between preference for color combinations and reaction time, we needed to consider the factors of the tone and interval distance of color combinations independently. The correlation coefficients between the preference evaluation scores and the reaction times are presented in Table 2, We may assume that there are two extremes of positive and negative preference categories respectively associated with light tones ($M_{preference}$ = 7, SD = ±2.5) and dark tones ($M_{preference}$ = 4, SD = ±3.2), such that the reaction time is shorter for items in the more liked category with higher evaluation scores, whereas inversely, in the disliked category, higher evaluation scores were correlated with longer reaction times.

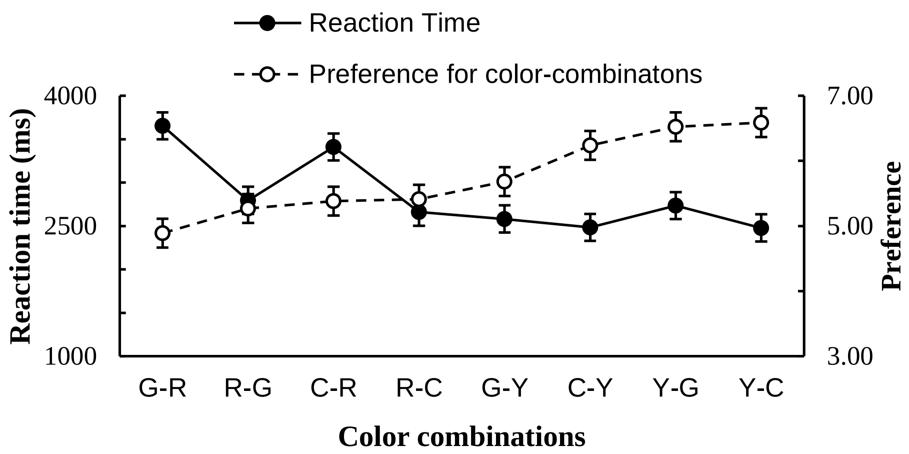
Table 2.
Correlation between preference and reaction time.

		Preference		
		Light tone	Vivid tone	Dark tone
Reaction time	Adjacent	-.10 *	-.04*	.48*
	Closer	-.15*	.10*	.34*
	Separated	-.19*	.07*	.16*

Note: Table 2 shows the correlation coefficient between the preference and reaction time. In the category of light tone, although the coefficient was small, there was still a negative correlation between preference and the reaction time regardless of interval distance. According to the tone become darkish, there was the positive correlation between them.

Additionally, we conducted a more detailed examination of the most liked color combinations such as Y & G, Y & C and most disliked color combinations such as R & G, R & C to re-analyze the relationship between these judgments and reaction time and identify a clear trend. The relatively disliked combinations such as R & G, R & C were associated with longer reaction times than the relatively liked combinations such as Y & G, Y & C ($t\ (1{,}220) = 7.01$, $p < .0001$; $t\ (1{,}220) = 3.86$, $p < .001$; $t\ (1{,}220) = 7.95$, $p < .0001$; $t\ (1{,}220) = 7.79$, $P < .0001$; etc.). It turned out that participants needed more time to judge a combination of undesirable hues. Figure 4 presents a summary of the average reaction time values and the likelihood evaluation for a total of eight combinations of pairs of R & C, R & G, Y & G, Y & C according to their left and right positions. Overall, the reaction times for colors receiving higher preference ratings were relatively short.

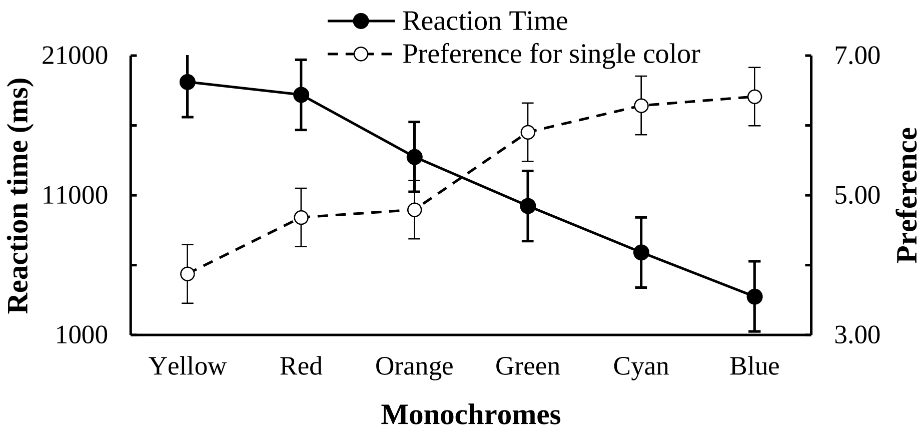
Figure 4.
Correlation results for color combinations.



Note: Figure 4 shows the relationship between preference for color combinations and reaction time. The left vertical axis denotes reaction time, the right vertical axis shows the preference for color combinations, which are arranged in order from least to most liked. Shorter reaction times were correlated with higher preference ratings.

Significant correlations were found between distance between colors and color-combinations, and the main effects of distances and color-combinations on reaction time were found ($F\ (22{,}440) = 2.20$, $p < .01$; $F\ (2{,}40) = 18.76$, $p < .01$; $F\ (11{,}220) = 12.41$, $p < .01$). According to the multiple correlations of the reaction time, the reaction times associated with disliked red-green and red-cyan combinations were longer than more liked color combinations as yellow-cyan or yellow-blue combinations (Figure 4). Moreover, significant negative correlations existed between single-color preferences and reaction time ($r = -0.42$, ** $p < 0.01$) (Figure 5).

Figure 5.
Correlation results for single colors.



Note: Figure 5 shows the relationship between preference for single colors and reaction time. The left vertical axis denotes reaction time and the right vertical axis represents the preference ratings. Colors are arranged from left to right in order of least to most liked. Shorter reaction times were correlated with higher preference.

4. DISCUSSION

Based on our results concerning the relationship between color preference and reaction time, we understood that participants tended to choose their liked colors more quickly than those they liked least, regardless of whether these be single-colors or color-combinations (see Figures 4 and 5). The correlation coefficient on the Table 2 supported our results. In addition, among colors in the more liked category, a preference for light tones had a small negative correlation with reaction time, whereas the evaluation for color preference in the relatively disliked category of dark tone had a positive correlation with reaction time. Earlier studies of reaction time were primarily conducted in the field of marketing. Aaker et.al (1980) reported that brand preference influenced reaction time such that they were nearly inversely proportional. Pullig, Simmons, and Netemeyer’s (2006) study using reaction times to measure the dilution of brand value demonstrated that longer response times imply declining brand value. Although Klein and Yadav (1989) suggested that response time did not directly consider likes and dislikes, they found a positive correlation between the difficulty of decision making and time. Haaijer et.al (2000) posited that shorter reaction times are often more desirable for humans. In a study of the relationship between monochromatic preferences and reaction times, Hovancik (2000) asked participants to choose one of the two monochrome colors and measured their reaction time, finding a strong negative correlation between preference and reaction time. Using an 11-point scale to rate tone- and color preferences is an approach for which the usefulness has been confirmed in both monochromatic research and marketing features such as the color combinations featured in branded products. It is unknown how coloring preference is determined, but preferences have been demonstrated to change based on empirically measurable factors such as region, age, and type of objects what they liked (Palmer, & Schloss, 2010), also may be related to their personality type, gender, culture. The judgment of likable feelings for color combinations is based on such individual differences. People perceive color combinations differently and sometimes form their impressions over time; thus, if you look at certain color combinations, their favorability will increase somewhat simply through a contact effect. Furthermore, people are frequently exposed to popular color combinations, which might further enhance their positive evaluations. There seem to be some specific color combinations that commonly receive high evaluations among individuals, as reflected in highly rated brands in consumer categories ranging from bags to clothing, he brand was more liked in the color combinations category. As brand preferences are earnestly acquired through experience, our reactions to color combinations might also correspond to an acquired likelihood evaluation.

However, it is notable that reaction times for single-colors were longer than for the color combinations, which indicates that people might decide more rapidly when choosing more complex combination of colors than when rating a single color. In our past experiments, we learned that single-color preferences do not affect judgements of color combinations even when the single color is included in the pairings (Jin & Kawabata, 2015). Moreover, our preference for color combinations appears to mostly depend on their harmony. Additionally, significant correlations were identified between color-pair preferences and color harmony through experimental data ($r = 0.70$, $p < 0.01$). At this point, we may conclude that when people are judging color combinations, At this point, we may conclude that it is the factor of harmony, which is quickly identified and absent in monochromatic contexts, that influences the speed of preference determination when people are judging color combinations, whereas preferences for single colors, might derive more from people's memories or imaginings of past personal experiences, which would extend the reaction time. Whereas preferences for single colors might derive more from people's memories or imaginings of past personal experiences, which would extend the reaction time. We learned that the preference for color closely relates to the evaluation of the harmony feeling of the combination of colors (Jin & Kawabata, 2015; Karen & Stephen, 2011; Naya et al., 1966; Ou & Luo, 2006; Palmer & Schoss, 2011; Szabó, Bodrogi, & Schanda., 2010). Harmony is also a value that has accumulated in individuals through various experiences and daily reinforcement in daily life. and it is likely to be the main constituent element in deciding the likelihood evaluation of coloration. Therefore, in this experiment, participants might have made determinations of simple likes/dislikes based on this harmony of color combinations. In the case of single colors, these presented a harmony with the background color; however on a background with low saturations (such as medium gray), there is less likelihood of any significant incompatibility due to a comprehensive evaluation that summarizes elements other than harmonies, such as a pure evaluation for that particular color obtained from personal experiences of particular items and feelings associated with that color, hence, the reaction time was longer for the reasons mentioned above. Moreover, the individual difference was more remarkable than color combinations. In the case of color combinations, since the evaluation has already determined according to harmony, it appears to be easier to make a judgement, as reflected in the faster reaction times.

In the future, we aim to conduct a more detailed investigation of reaction time and harmony of color combinations and compare them with the reaction time of the preferences of color-combinations or single colors. Moreover, we will aim to clarify whether more attention should be paid to the more harmonious color-combinations. It is necessary to explore the mechanism behind color palatability as determined by humans and related behavior indicators by examining the gaze count, the gaze.

5. CONCLUSION

In short, our results indicated that evaluations of color preference had a small negative correlation with reaction time in the more liked category of light tones, whereas this rating had a positive correlation with reaction time in the disliked category as dark tones. In addition, the reaction time for single-colors was longer than for the color combinations. These results align with previous studies that demonstrated a significant relationship between preference for objects and reaction time.

REFERENCES

Aaker, D. A., Bagozzi, R. P., Carman, J. M., & MacLachlan, J. M. (1980). On using response latency to measure preference. *Journal of Marketing Research, 17*(2),237-244.

Dashiell, J. F. (1937). Affective value-distances as a determinant of aesthetic judgment times. *American Journal of Psychology, 50*(1/4), 57-69.

Haaijer, R., Kamakura, W., & Wedel, M. (2000). Response Latencies in the Analysis of Conjoint Choice Experiments. *Journal of Marketing Research, 37*(3), 376-382.

Hovancik, J. R. (2000). Using microcomputers in the undergraduate laboratory. In M. E. Ware & D. E. Johnson (Eds.). *Handbook of demonstrations and activities in the teaching of psychology* (pp.244-246). Mahwah, NJ: Lawrence Erlbaum Associates.

Jin, S. & Kawabata, Y. (2015). Harmony of two-color schemes in things and space. *Proceedings of the 79th Annual Convention of the Japanese Psychology Association*, 745.

Karen, B.& Stephen, E (2011). Aesthetic response color combination: preference, harmony and similarity. *Attention Perception & Psychophys*. (73), 551-571.DOI 10.3758/s13414-010-0027-0. http://dx.doi.org/10.1371/journal.pone.0102888(2016-06-28).

Klein, N. M. & Yadav, M. S. (1989). Context effects on effort and accuracy in choice: an enquiry into adaptive decision making. *Journal of Consumer Research*, *15*(4), 411-421.

Lee, T-R., Tang, D-L., & Tsai, C-M. (2005). Exploring color preference through eye tracking. *AIC colour 05-10th Congress of the International Colour Association*, 333-336.

Maki, K., Ide, S., & Kato, S. (2016). Color combination preference expression setting in the reasons for the preference as intermediary variables. *Journal of the Color Science Association of Japan, 40*(4), 155-166.

Naya, Y., Mori, N., Tsujimoto, A., Ikeda, J., & Namba, S. (1966). On Estimation of Goodness of Harmony in two-Color Harmony from Physical Quantity (Study on Color Harmony Part 3). *Electric Laboratory Bulletin*. *30*(2), 161-178.

Ou, L. & Luo, M. R. (2006). A colour harmony model for two-colour combinations. *Color Research and Application, 31*(3), 191-204.

Oyama, T. & Miyata, K. (2012). Effects of hue difference, lightness difference, and saturation difference on emotional effect of two color schemes. *Journal of the Japan Color Science Association*, *36*(4), 277-282.

Palmer, S.E., & Schloss, K.B. (2010). An ecological valence theory of human color preference. *Proceedings of the National Academy of Sciences of the United States of Americ*a, 07(19), 8877-8882.

Pullig, C., Simmons, C.J., & Netemeyer, R. G. (2006). Brand dilution: when do new brands hurt existing brands? *Journal of Marketing*, 70(2), 52-66.

Shipley, W. C., Coffin, J. I., & Hadsell, K. C. (1945). Affective distance and other factors determining reaction time in judgments of color preference. *Journal of Experimental Psychology, 35*(3), 206-215.

Szabó, F., Bodrogi, P., & Schanda, J. (2010). Experimental modeling of colour harmony. *Color Research and application*, *35*(1), 34–49.

AUTHORS INFORMATION

Full name: Shengai Jin
Institutional affiliation: Hokkaido University, Department of Psychology
Institutional address: Kita 10, Nishi 7, Kita-ku, Sapporo, Hokkaido 060-0810, Japan
Short biographical sketch: Shengai Jin has completed doctoral course in the graduate school of letters at Hokkaido University in Mar, 2018. She is a member of the Japan Color Science Association, Japan Psychology Association, Japan Visual Society.

Full name: Yasuhiro Kawabata
Institutional affiliation: Hokkaido University, Department of Psychology
Institutional address: Kita 10, Nishi 7, Kita-ku, Sapporo, Hokkaido 060-0810, Japan
Short biographical sketch: After receiving his Ph.D. from Hokkaido University (Sapporo, Japan) in 1993, he held research posts at Ritsumeikan University (Kyoto). In 1999, he returned at Hokkaido University, where he now serves as a Professor in the Department of Psychology. His research interests have included color vision modeling in a changing visual environment, color pattern recognition, and memory.