

# Color Perception and Its Application with Big Data Driven Examination

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## Abstract

**Background/Objectives:** This study finds conceptual map of associated words on six major colors in human brain. It also delivers insight into color and its possible application of these findings to commercial fields such as advertisements.

**Methods/Statistical analysis:** To find associated words on six major colors and relationships among colors, social network data sets are collected and analyzed with the techniques of text mining, association analysis, and data visualization. A survey on people's perception on six colors are also conducted and analyzed. Network analysis of textual data on colors and applications are performed to find the best color for an application such as advertisement on travel and insurance companies as examples.

**Findings:** This study shows that each color has associated words, and colors are associated together. The color concepts can be represented with colors and their associated words graphically. These can be applied to find the best color images for words.

**Improvements/Applications:** The findings from this study can be applied to diverse areas such as an advertisement, marketing, and design. This study proves that cognitive enhancement using color perception is possible.

**Keywords:** Color Perception, Cognitive Analysis, Associated Words, Text Mining, SNS Mining.

## Article History

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## 1. Introduction

Color covers a wide range of studies from science to psychology. In some way, it is the results of its implementation in social life. Social scientists are now very often interested in the way color associates with social life[1]. It also plays an important role within a wide spectrum of business research in marketing and

communicationsspecifically. Several studies have indicated the importance of color on impacting consumer perceptions and influencing purchase behavior[2]. There are claims that visual resources increase human awareness by more than 80%. Color impacts 80% of visual perception and memory. Thus, color also has a significant role in human's visual

memory. In recent years, marketers are interested in the affects of colors on customer's perception and behavior.

Color exists under all three elements – light source, object, and observer. Color is perceived through light receptors within the eye, followed by brain processes[3]. The retina of an eye contains two forms of photosensitive cells – rod and cone. Rods detect light that is necessary for colors to exist. The cone cells are sensitive to light of different wavelengths colors – short (blue), medium (green), and long (red)[4]. Light source is consisted of wavelengths of light - measurements of the spectral power distribution of light sources. It has been reported that the color spectrum with a prism which white light refracted with a prism[5]. The difference in any three factors may show a different result in color vision and perception. Colors, in general, influence human performance and cognitive interpretation; however, the activation-related affect is not straightforward[6].

Visual perception of color refers to the physical color perceived from the eye to the brain. Ewald Hering proposed *opponent-process* theory which is a model for color perception. He explained how the photoreceptors from the eye transmits to the brain[7]. Ample extent researches indicate that color also stimulates humans' minds to recall memories from their previous experiences. This color information is processed and stored in visual memory which is located in one of cognitive systems. The stored color information appears when people trigger the nomenclature of color.

A few research addresses how nomenclature of color is used and associated on social media platform. As consumers are utilizing digital platforms to communicate contents, this paper searches consumers' perceptions on color and its application from social platforms – how people associate color and words, and the connotation of color in consumers' minds[8].

The purpose of the study is to find the

relevance between color and its meaning on social media platforms. This study provides an insight into the digital nomad's perspective of color to implement to various fields of marketing, communications, and advertisements.

Color perception is explained by David Williams, Allyn Professor of Medical Optics and director of the Center for Visual Science. "We were able to precisely image and count the color-receptive cones in a living human eye for the first time, and we were astonished at the results. We've shown that color perception goes far beyond the hardware of the eye, and that leads to a lot of interesting questions about how and why we perceive color"[9].

The importance of color perception has been widely discussed in recent studies. For example, there are argues that even normal observers may see color perceptions differently among themselves. The authors indicated the examination of the variations in hue-scaling functions showed individual differences[10]. Gong investigated the applications of color appearance models to representing the perceptual attributes for digital images. They argue that the model may supply more accurate methods for perceiving image brightness and colorfulness[11].

Colors influences emotions and the impact on perception and behavior is crucial. Previous researchers claimed the association between color and emotions exists. It is known that yellow, orange, and blue as happy colors, and red, black and brown as sad colors. While they stated red as gravity and dignity as well as grace and attractiveness, some researchers relate to love and excitement[12]. Researchers on colors indicated that atmospherics such as noise, sizes, shapes, scents, and colors could help create attention, convey messages, and create feelings that might increase purchase probability. The effects of such atmospherics have been demonstrated to influence emotional responses and behavioral intentions. Although, color is related to feelings about

retail environment it also affection distraction and influences anxiety. Color are psychologically related to different words as in the table below:

**Table 1.** Color and Its meanings in Literature

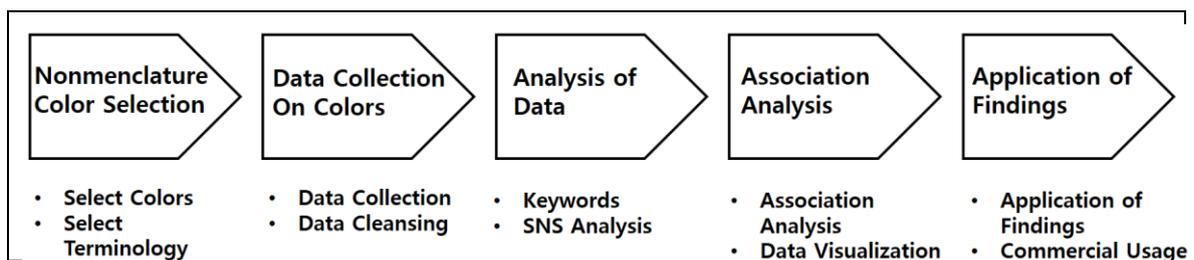
Color	Emotions
Red	energy, excited
Green	peace, restful
Yellow	joy, melancholy
Blue	calm, soothing
White	purity, innocent
Black	evil, unhappy

Black is normally related to boldness, formality, mystery, strength, luxuriousness, and seriousness. White represents safety, purity, freshness, cleanness, and contrast. Red gives feeling of love, anger, passion, power, excitement,

and intensity. Blue means calmness, serenity, peacefulness, tranquil, orderly, stability, and security. Green is related to nature, safety, peaceful, restfulness, soothing, and luck. Yellow represents warmth, joy, sunshine[13].

## 2. Materials and Methods

The current study was performed with a series of methods as shown on Figure 1. The research examines the color theories in three parts – color properties, color perception, and color psychology. The color is selected based on the color fundamentals and the data frequency. The color data is collected from diverse media such as SNS and news. Text crawling, text analysis, association rule, and data visualization methods are used as tools in this study.



**Figure 1.** Research Process

### 2.1. Data and Analysis Methodologies

The research investigates the fundamental of color theories from color properties, color perception, and color psychology to understand the effects related to color and the findings from the experiment. Color properties introduces the fundamental of color theories – from the eye to the light wavelength. Color perception explains how people perceive color followed by color psychology. It explains the meaning of colors from an academic color perspective to compare the differences with our results.

#### 2.1.1 Nomenclature Color Selection

Six major colors in this study are selected based on Ewald Hering's *Opponent Process Theory* – red, green, yellow, blue, white, and black. The theory provides a visual understanding of human color perception. Based on the colors, the nomenclature words

were selected on two factors – official color name in noun; and most used term in English color dictated in Korean. The color texts used in the experiment are in the order of adjective, noun, and English noun in Korean version. In Korean language, there are numerous ways in which a single color is described or named; however, the research focuses on the official color term. Therefore, given words may be written in different names

#### 2.1.2 Data Collection on Colors from SNS Data

The color data was retrieved from social network data. The results were obtained from various media services including Twitter, blogs, and news, and articles from January 1, 2018 to December 31, 2018. The number of messages in the SNS/media data is about 940,000. The selected colors of black, white,

red, green, blue, and yellow were found to be most commonly referred and used in online. The retrieved texts were cleaned and reorganized for association analysis. The words relating to colors were selected using the analysis.

**2.1.3 Verification of Data with Survey**

The verification of the color nomenclature data was undertaken by a survey. It provides an insight into the color perception on social media platform and in real experiment. One hundred sixty-nine participants (89 females, 80 males) participated in partial fulfillment of course requirements from July 1 to July 31, 2019. They were assigned to the complete the online survey on associated words on 6 colors (red, yellow, green, blue, white, and black).

**2.1.4 Methodologies**

Text Mining refers to an emerging technique to extract meaningful data patterns from unstructured textual data such as documents, news, SNS, web pages, and reviews[14].

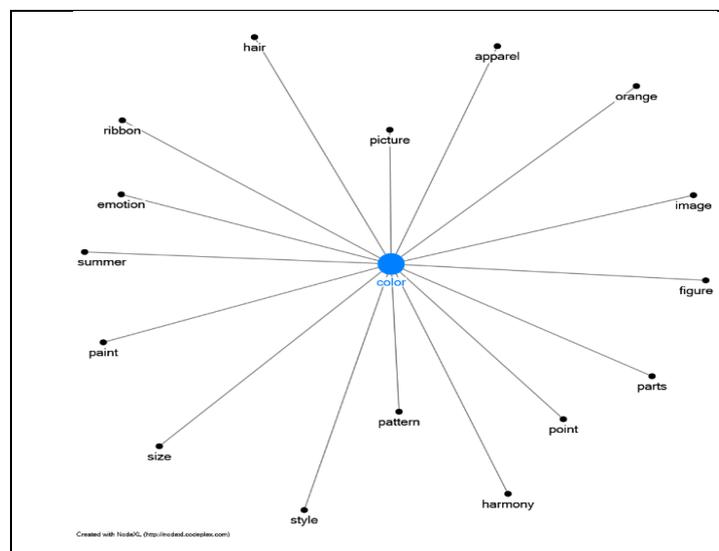
Text mining observes a pattern of findings in text suggesting and forecasting the upcoming trends and strategies from peoples' current data. Social network data mining refers to the analysis of social data from SNS[15].

The Association Analysis is most often used to establish relevance between two variables and to provide a solution for the market basket problem; however, the Association Analysis has rarely been used to analyze textual colors on social media. The process expects the data input grid to have binominal (true or false) data with items in the columns and each transaction as a row[16].

**3. Analysis of Data and Color Perception in Human Brain**

**3.1 Color Perception Analysis**

The present study shows how people associate the word 'color' on social media platform from the analysis of social data. Figure 2 shows related words regarding colors in human brain. Picture and pattern have strongest relationship with color.



**Figure 2. Color and Its Related Words**

Table 2 shows six major colors and associated words with those six colors. For example, the words emotion and photo, and design have top frequencies among related words, meaning highly associated with the color red. The words emotion, photo, and hair have close relationship with 'yellow.' The words cheap, hair, and

emotion have close relationship with the color 'green'. The words emotion, photo, and like have close relationship with the color blue. The words couple, secretive, and love have close relationship with the color white. The words hair, part, and emotion have close relationship with the color black.

**Table 2. Six Major Colors and Their Associated Words**

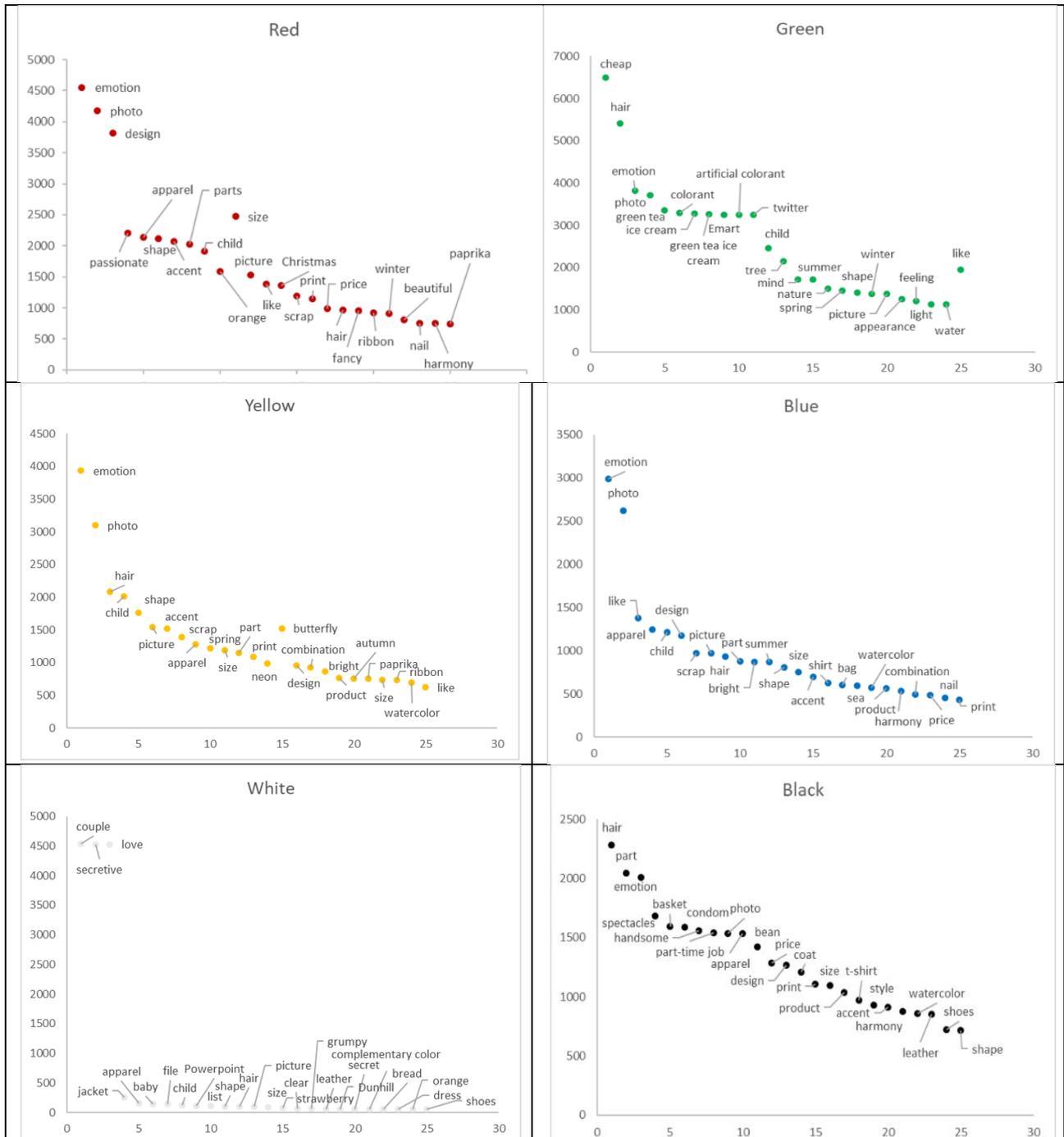
	Red		Yellow		Green		Blue		White		Black	
	word	frequency	word	frequency	word	frequency	word	frequency	word	frequency	word	frequency
1	emotion	4551	emotion	3931	cheap	6496	emotion	2987	couple	4535	hair	2282
2	photo	4174	photo	3099	hair	5409	photo	2624	secretive	4528	part	2044
3	design	3813	hair	2081	emotion	3826	like	1378	love	4528	emotion	2007
4	passionate	2211	child	2015	photo	3707	apparel	1242	jacket	255	spectacles	1685
5	apparel	2140	shape	1761	green tea	3351	child	1216	apparel	162	basket	1596
6	shape	2117	picture	1541	colorant	3298	design	1173	baby	151	condom	1588
7	accent	2072	accent	1519	ice cream	3278	scrap	970	file	149	handsome	1557
8	parts	2022	scrap	1393	green tea ice cream	3265	picture	967	child	121	part-time job	1540
9	child	1914	apparel	1278	Emart	3249	hair	929	Power point	119	photo	1538
10	orange	1589	spring	1217	artificial colorant	3247	part	879	list	119	apparel	1536
11	size	2477	size	1922	twitter	3247	bright	871	shape	107	bean	1421
12	picture	1530	part	1150	child	2466	summer	866	hair	103	price	1283
13	like	1388	print	1090	tree	2147	shape	809	picture	99	design	1269
14	Christmas	1367	neon	983	mind	1725	size	749	size	87	coat	1209
15	scrap	1190	butterfly	1523	summer	1723	accent	699	strawberry	85	print	1107
16	print	1150	design	961	nature	1500	shirt	627	clear	69	size	1094
17	price	985	combination	931	spring	1461	bag	603	grumpy	66	product	1039
18	hair	973	bright	870	shape	1410	sea	598	leather	63	t-shirt	973
19	fancy	953	product	764	winter	1383	water color	573	Dunhill	63	style	932
20	ribbon	920	autumn	760	picture	1381	product	562	secret	63	accent	910

Figure 3 shows pictorial representation of colors and their associated words in graph. Y axis represents frequencies of words and X axis represents ranks of these frequencies on each of six colors. The

associated the words on each color can be categorized into three groups: emotion-related words, photo-related words, and nature-related words. Emotion-related words include emotion, harmony, and

image. Photo-related words are photo, picture, hair, apparel, dress, ribbon, print,

style, size, accent, shape, and part. Nature-related words include summer and orange.



**Figure 3. Text-Mining Results of Colors and Their Associated Words**

On the other hand the most probable words related to the word red when people think about the color 'red' are blood, fire, and rose. There are common words between two sets of associated words, one

from SNS(Media) and the other from survey. The color 'blue; has two common words of sea and summer between associated words on blue from SNS(Media) and survey. The color 'green'

has common words of spring, green tea, summer, nature, and tree between two sets of words, one from SNS(Media) and the other from survey. The color 'black' has a common word of hair between two sets of words, one from SNS(Media) and the other from survey. The images of colors are quite different in the case of red compared to the case of blue and green. The study shows that SNS(Media) does not always represent the images of words accurately. Social data shows part of the whole information or images in human brain. Therefore, social data analysis is used to predict what is in human mind. These differences may have been reflected from behavior and cognition.

For example, when we think of a color 'red', our brainstry to find the most associated words for the situation. The brain recognizes the situation which affects the word choices. Then the morphological rules describe the meaning units of words. The word 'red' is most commonly used with the word emotion, photo, or design in SNS. In the experiment, participants associated 'red' to the situation and/or condition - sun, apple, and heat.

### 3.2 Association Analysis on Colors

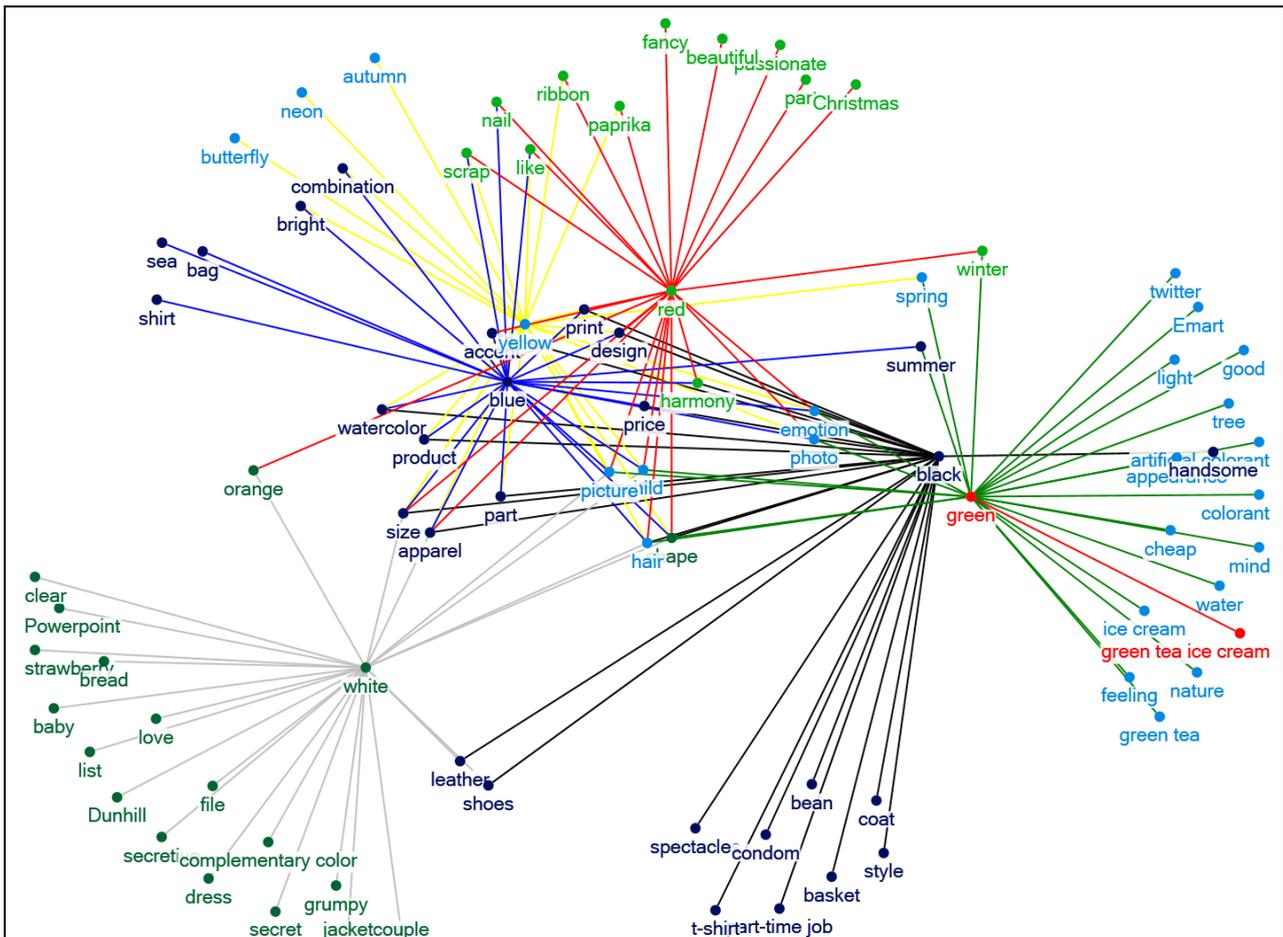
Figure 4 shows word association from both survey and social data analysis. The visual data illustrates that the associated words related to a specific color from social data analysis are different from the

words from the survey. The most commonly used words in SNS(Media) regarding the color 'red' are emotion, photo, and design; whereas sun, apple, and heat. Blue shows two words (sear and summer) from both categories. People resembled the same words for yellow, which included butterfly, bright, spring, and child. Green, the most closely associated color, was perceived as words such as spring, green tea, summer, nature, and tree. White showed no relevance between the SNS and survey—participants related words such as couple, secretive, and love on SNS compared to wedding dress, paper, and purity on the survey. Interestingly, black had one common word – hair – which was also the most frequency in SNS and the survey. The result indicated that most participants perceived hair to be black. Other results of black in the survey showed words related to death, dark, and, suit, in contrary to the words (hair, parts, emotion) from SNS.



Figure 5 depicts network analysis of associated words on 6 colors. This study shows the color-to-color relationship when mentioning words associated to colors. For example, people mentioned leather the colors of white and black appeared. The word 'summer' was associated to green and blue. Surprisingly, all six colors had the same word 'hair' on SNS. There were five

colors (red, yellow, green, blue, and white) which related to words such as child, shape, and picture. The common words – emotion and photo - appeared for chromatic colors of red, yellow, green and blue. People tend to associate more emotions and photos with colors than achromatic colors.



**Figure 5** The SNS Image of Colors and Their Associated Words in Network Graph

Red, the most popular color, showed the high frequency overall in all colors except white. The highest association is found in blue and yellow; however, green showed a high frequency. It indicates that the words have the most common association among the colors. The highest frequency of green was red, followed by blue. Green showed the least association with black and white. Yellow illustrated a close relationship with red of 120,000 frequencies. Yellow was mentioned more often with blue and green, than that of white and black. Blue showed the highest frequency relating to red; however, white

was least associated. Yellow, complementary color of blue, showed less relevance. Black showed slightly different relations among all colors. It showed the lowest frequency and it was closely related to white, followed by red. The association words of black and white include mostly photo-related words such as jacket, apparel, shape, hair, picture, size, leather, dress, and shoes.

**4. Applications of Findings**

As a word can have polarity of (+) or (-), a word can also have a representative color of

red, blue, green, yellow, white, or black. The words reminding each color can be found with text mining. The examples in this study are travel and insurance. There are questions like “what are the best color when they advertise travel and insurance?”. These questions are important question in advertisement industry. Alone with sounds, texts, and images, colors are also known to

influence the effect of advertisements.

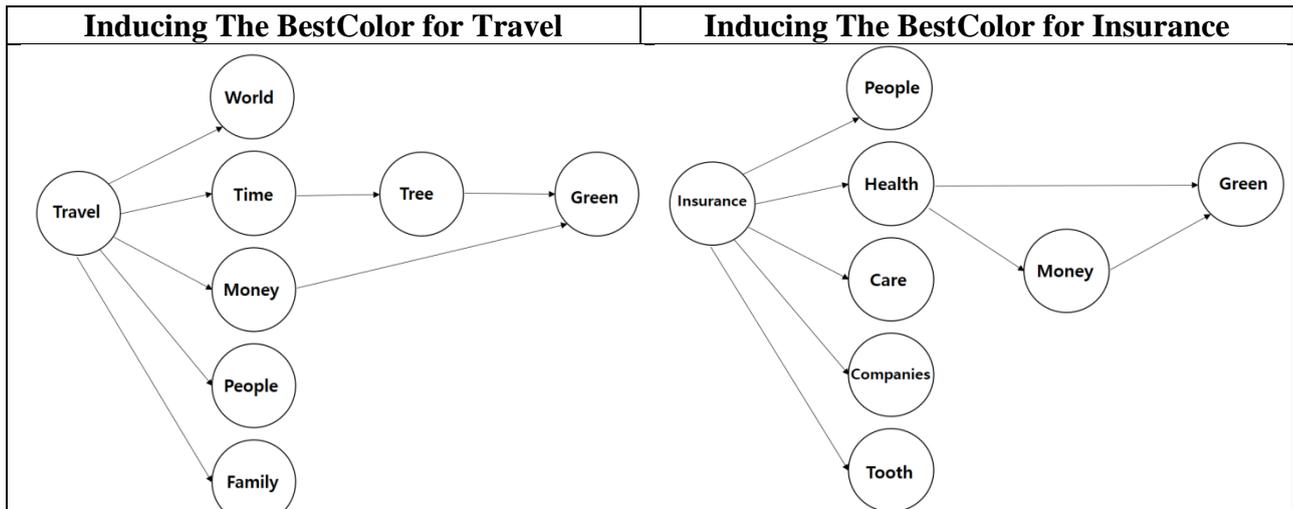
Table 3 shows words associated with the words travel and insurance. The top meaningful words associated with travel are time, world, money, people, and family. The top meaningful words associated with insurance are health, people, care, companies, and tooth.

**Table 3. Associated Words on Travel and Insurance**

Travel		Insurance	
Word	Frequency	Word	Frequency
time	301	health	1577
amp	290	people	1327
world	259	care	1122
money	186	companies	812
more	181	amp	581
new	156	conditions	575
coffee	145	days	565
people	142	new	553
need	141	today	547
want	133	pre	542
love	125	existing	537
go	124	before	530
family	123	tooth	523
via	118	republicans	520
pearl	114	against	509
city	110	election	498

As shown in Figure 6, the most important and highly associated word with the word travel is time. The study finds the closest word related to the word time is tree. The most associated color with tree is green. The most associated word with the word money is also found to be green. The color representing the word travel is found to be the color ‘green’ in this study. The color green is the best color which can be used when they advertise travel. The closest word related to the word insurance is found to be

health. The closest word related to the word health is found to be money. The closest color, among six major colors, to the health is found to be green. The closest word related to the word money is also found to be green. The study also found that the best color regarding the word insurance is the color green. In both travel and insurance, the color ‘green’ better be used in their advertisements to enhance effect of the advertisements.



**Figure 6. Color Selection for Travel and Insurance**

### 5. Conclusion

This study shows color concepts and their applications in advertisements. To find associated words on six major colors, SNS data sets are collected and analyzed. Furthermore, the study finds the cognitive representations of color in human brain through actual surveys on colors and their images. The study shows colors and their related words from the analysis of social text data using big data methods such as text mining, association analysis, and data visualization. The results can be applied to enhancement of product sale in marketing and color psychology.

With the practical examples of advertisement in travel and insurance industries, best colors for these two commercial cases are analyzed. The study suggests a frame work to find the best color representing a word from neurological and cognitive point of view. More importantly, this new approach provides a fundamental understanding of colors used on social media and human brain.

The study should be acknowledged that the limitation lays in surveys. The present survey results may not be replicated with the group of the same age and culture. The participants on the survey on the colors and their images are mostly students such as undergraduates or graduates. The classification of colors may

slightly differ by individuals as it was only conducted with words. Furthermore, there can be differences in color perception and their association of words depending on trends and time periods. Future research approaches its color associations in various cultural backgrounds and expands its variables of color testing. It is expected that the research of color and perception provides insights into social media platforms and its diverse applications.

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