Can Eyes Smell?

Color Hue-Tone and Fragrance Intensity

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Abstract: Previous studies have proved that color is an important perceptual variable in odor association and identification. Here this research investigates aspects of the cross-modal associations between color and fragrance in greater depth delving into the topic of whether the associated intensities of fragrances vary systematically with hue and tone of colors. Sixty-seven subjects rated the intensities of 4 typical fragrances families (fresh, floral, oriental, and woody) for 33 color samples, which have different hue and tone parameters, via a computer monitor screen. The statistical analysis showed that the associated intensities of all the fragrances had characteristic distributions across 10 hues of the color samples. The cross-modal relationship between color tone (particularly, lightness attribute) and fragrance intensity appeared to be dimensional, except for the oriental type. These findings confirm the existence of synthetic interactions between vision and olfaction in perfumery.

Key words: Color Hue-Tone, Fragrance Intensity, Cross-modal Association, Commercial Perfume.

1. Introduction

During their everyday lives, people obtain sensory impressions by seeing, hearing, smelling, tasting, and touching surrounding objects or environments simultaneously. In light of these sensory experiences, researchers have extensively studied a variety of cross-modal correspondences in the fields of psychology, physiology, neuroscience, design, and so on. Visual-olfactory correspondences particularly have begun to receive more attention in painting, food, and perfume context because the appropriate appearance (color) of objects can increase the accuracy of their odor association or identification. For example, Martin (1909) discovered that olfactory impressions were among the sensory experiences reported by subjects viewing reproductions of painting [1]. According to Zellner at al. (1991), congruent color-odor combinations for fruit beverages can facilitate the identification latency and accuracy for the odor, and the color can also alter liking for the beverage odor [2]. In the perfume industry, it is important to apply appropriate colors to bottles and packages of perfume products in order to effectively express the mood of the fragrance inside the bottles [3]

To date, a variety of color-odor matching tests have advocated the existence of the cross modal relation between color and odor. Gilbert et al. (1996) found that 13 out of 20 test odors (fragrance material) had characteristic Munsell hues, and there was significant variation in Munsell chroma and value [4]. A year later, Kemp and

Gilbert (1997) conducted the follow-up color-odor matching test with Munsell color chips and five fragrance materials presented at three concentrations [1]. They suggested that color lightness varies inversely with perceived odor intensity. However, Zellner and Whitten (1999, p 602) found that although color intensity has some influence on the strength of the color-induced odor enhancement, it does not have a consistent pattern of effect [5]. Recent research by Dematte at al. (2006) discovered that people tend to more rapidly and accurately match color and odor with having a stronger association (e.g. strawberry and pink) than to those having a weaker association (e.g. spearmint and pink).

More practically in the perfume industry, Schifferstein and Tanudjaja (2004) conducted a matching test using 14 commercial perfumes (instead of fragrance materials) and matching colors (Natural Color System instead of Munsell), and then revealed matching colors differed mainly on blackness (brightness), and less on chromaticness (saturation) and hues [6)]. Though a blind matching test on three commercial perfumes using the colors (IRI Hue & Tone System), Kim (2008) showed the perfumes were related with characteristic hues and their fragrance notes (top, middle, and base) had significant variation in tone [7].

Although the previous research proved that the cross-modal associations between color and fragrance were not found consistently for all odors, there were significant differences in color-fragrance matches according to color dimensions (hue, value, and saturation). To provide more support for the robust existence of color-odor correspondences, this research delves into the topic of whether the associated intensities of fragrances vary systematically with hue and tone of colors. For four typical fragrance types of commercial perfumes, a color-fragrance marching test was performed using color patches (IRI Hue & Tone System) which have hue and tone parameters. The proposed hypotheses of this research are twofold:

Hypothesis 1: The associated intensities of the four fragrances have characteristic distributions across the color hues.

Hypothesis 2: The associated intensities of the four fragrances vary systematically with the color tones.

2. Experiment

2.1 Subjects

In 2008, this experiment was conducted with students who were taking a “Color Practice” course at K University in Korea. During the course, these students were given an opportunity to cultivate knowledge on fragrances and colors of commercial perfumes via lectures and assignments. Sixty-seven university students (32 males and 35 females) with ranging in age from 19-24 years (M age=20.18 years, SD=.737) participated in the experiment. Subjects were screened by self-report for normal sense of color vision based on their previous color blindness diagnoses using the Ishihara Color Test, which consists of a number of colored plates that contain a circle of dots appearing randomized in color and size [8]. Subjects also had a normal sense of smell with no history of olfactory dysfunction.

2.2 Materials

With referring Michael Edwards' Fragrance Wheel [9], which classified fragrance into the five standard scent families, four distinctive fragrances were selected as odor stimuli of the experiment: fresh, floral, oriental, and woody. Fougĕre family, however, was excluded since they are a large family of scents that usually contain fragrance elements from each of the other four families [10]. Figure 1 illustrates sub-groups of the four fragrances on the Fragrance Wheel.

Visual stimuli were selected from the Hue and Tone 120 color system [11], which was developed by IRI Color Design Institute Inc. This system describes a two-dimensional color space based hue and tone parameters. Hue refers to a pure color without tint or shade. Tone indicates the result of the interaction of two factors: lightness or value, and saturation or chroma. Along with 10 achromatic colors, 110 chromatic colors are arranged by 10 hues (R-YR-Y-GY-G-BG-B-PB-P-RP) along the horizontal axis and 11 tones (vivid-strong-bright-pale-very pale-light grayish-light-grayish-dull-deep-dark) along the vertical axis. In order to enhance subjects' discrimination performance, the 11 tones were grouped into three groups and each group's representative tone was chosen: vivid, pale, and deep. As presented in Figure 2, color lightness increases from deep, vivid to pale tones while color saturation increases from pale, deep to vivid tones. Finally, the experimental color samples consisted of 30 chromatic colors (10 hues X 3 tones) and 3 achromatic colors (white, medium gray, and black).

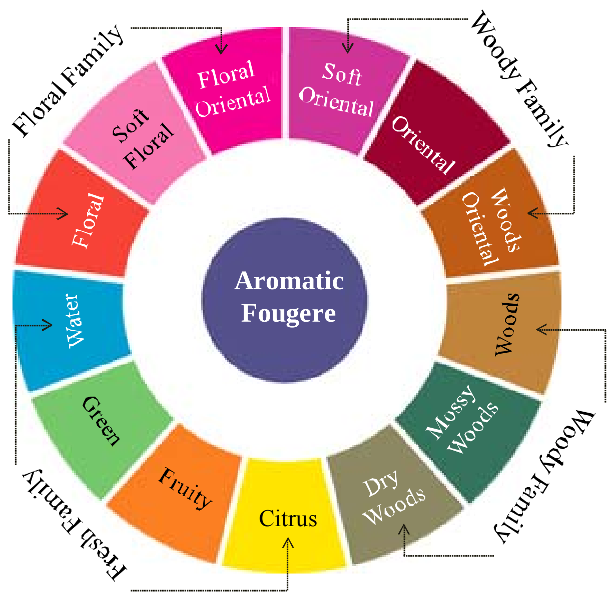

Figure 1. The Fragrance Wheel (four families and their sub-groups)

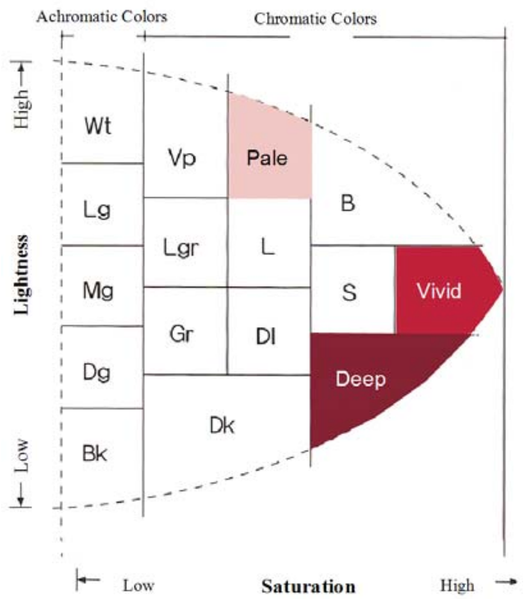

Figure 2. IRI color tone classification according to lightness and saturation

2.3 Procedure

The IRI Hue and Tone 120 color system has two versions based on RGB and CMYK color models. The 33 color samples selected from the system were displayed by the corresponding RGB values on a computer monitor. The odor stimuli were suggested in written words with the explanation on popular fragrance materials of their sub-groups (e.g. fresh family: (1) citrus- lemon, mandarin, and grapefruit, (2) green- green tea leaves, fresh herbs, and vine leaves, (3) water- wet air, ice, and cool dew). For each color sample, 67 subjects rated the evoked intensities of the four fragrance families using a 7-point Likert scale, with 7= "very strong" and 1= "very weak."

Before the experiment, the subjects were also trained for discriminating among these four fragrance families though smelling diverse commercial perfumes in each family during the “Color Practice” course. Although some of the suggested fragrance material lists might occur the subjects’ word-visual experiences, these experiences also helped them to associate more accurate visual-olfactory relationships.

3. Results

Several studies have asserted the generality of a gender difference in odor perception [12,13]. Perfumes’ scents particularly can have more gender-related differences. In general, they are developed by targeting the specific gender groups even though some products are unisexual: therefore, the gender’s characteristics and preferences influence fragrance materials, product concepts, bottles, and packaging of the perfumes. In this vein, this research also investigated whether a gender difference exists in the associated intensities of the fragrances across the 30 chromatic color stimuli (10 hues X 3 tones). Concerning statistical analysis, a t-test was performed for each fragrance type using the two gender groups (male: *n*=32, female: *n*=35) as independent variables at the 0.05 significant level. The results, as shown in Table 1, indicate the gender influenced the associated fragrance intensities for just few color stimuli. However, the floral fragrance showed significant gender differences across a wider range of the hues (GY, G, GB, B, and PB) and tones (vivid and deep) than the other fragrances. This tendency could be caused by the difference in the subjects’ knowledge or experiences with the floral scents, which are largely used in the female perfumery.

Table 1. The colors with significant gender differences in the associated fragrance intensities ($p<0.05$)

	Vivid	Pale	Deep
1. Fresh	GY	R, GY	GY
2. Floral	GY, G, GB, B, PB	Y, B, RP	Y, GY, G, GB, B, P
3. Oriental	-	-	B, PB
4. Woody	RP	YR	GY, G

The following subsections prove the aforementioned two hypotheses described in Chapter 1.

3.1 Hypothesis 1: The associated intensities of the four fragrances have characteristic distributions across the color hues.

The 10 color samples in the vivid tone are pure colors (hues) without tint and shade; therefore, the means of the intensity ratings of the four fragrance types were calculated across these colors in order to compare dominant hues related with the fragrance types. For each fragrance, an analysis of variance (ANOVA) was performed to determine whether the means among the 10 hue groups significantly differ after converting the 10 hue variables into one dependent variable. All reported differences between means were statistically significant at the 0.001 level for the all fragrances: fresh ($F_{(9, 660)}$=18.771, p=0.000), floral ($F_{(9, 660)}$=58.682, p=0.000), oriental ($F_{(9, 660)}$ =4.301, p=0.000), and woody ($F_{(9, 660)}$ =20.695, p=0.000). The below radial chart, as shown in Figure 3, visualizes the existence of differences in mean fragrance intensity ratings of the four fragrances across the 10 hues at the same time.

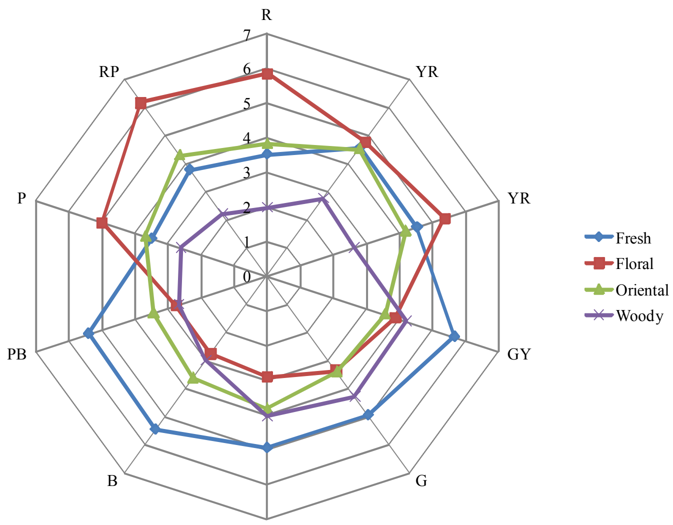

Figure 3. The radial chart showing mean fragrance intensity ratings of the four fragrances across the 10 hues together

In addition, by illustrating mean intensity distributions across the 10 hues for each fragrance type (see Figure 4), characteristic hue distribution patterns were found in terms of warm and cool color images. From the dominant colors for each fragrance in Figure 4, it can be seen that the cooler hues are, the stronger the associated intensities of fresh and woody fragrances become while the intensities of floral and oriental fragrances are opposite. In the case of fresh and woody fragrances, their associated fragrance intensity increased as the color stimuli become cooler. On the other hand, the warmer colors are, the stronger the associated intensities of floral and oriental fragrances become. Particularity, floral and woody types have a more distinctive tendency to have different intensities between warm and cool colors. Compared to the other fragrance types, oriental type has little variation in hue distribution. It can be assumed that the subjects had not enough knowledge on scents and materials of the oriental fragrance type.

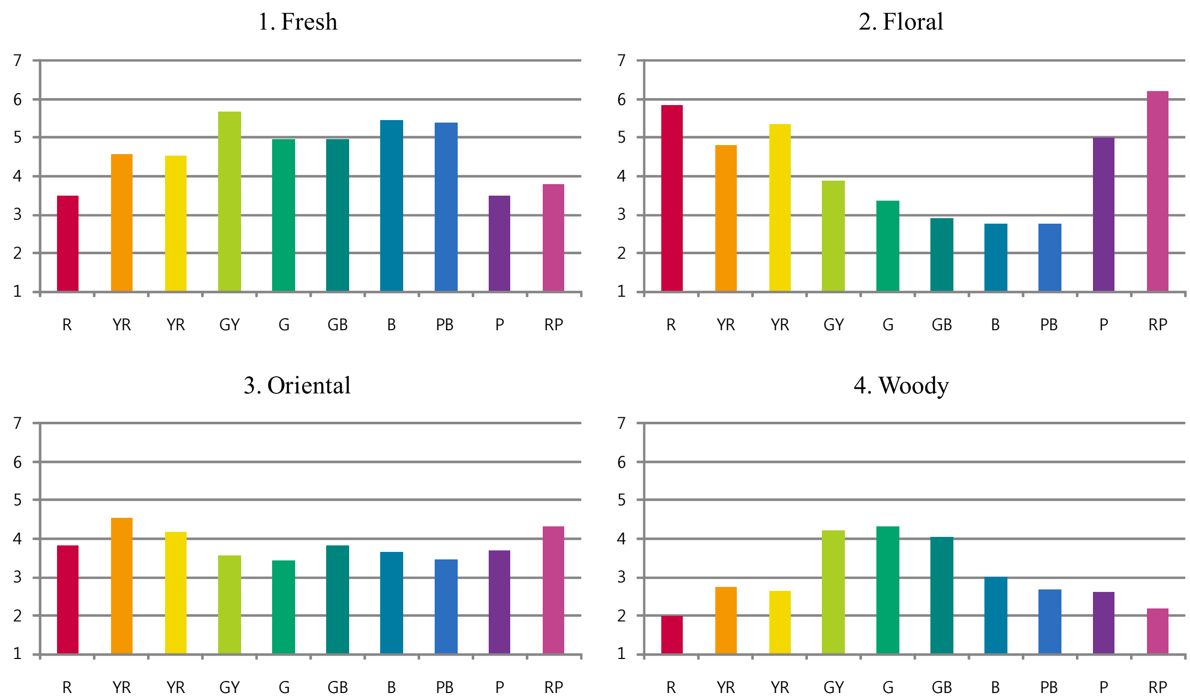

Figure 4. Four bar charts showing mean fragrance intensity ratings of the four fragrances across the 10 hues individually

In order to investigate relationships among the four fragrances, the Pearson correlation was measured by pairing the mean intensity ratings of the four fragrances. Among 12 pairs of the four fragrances, the following four pairs showed significant correlations at least at the 0.05 level. Hue distributions of fresh-floral fragrances showed a strong negative correlation (r=-8.28, p= 0.003, α=0.01 (2-tailed)). Floral-woody fragrances also show a relatively weak negative correlation (r=-0.660, p=0.038, α=0.05 (2-tailed)). Fresh-woody (r=0.674, p=0.033) and floral-oriental (r=0.65, p =0.042) had a positive correlation at the 0.05 level (2-tailed). Based on these correlation results, two-dimensional maps for the four fragrance pairs were illustrated according to mean intensity ratings associated from the 10 hues, as shown in Figure 5.

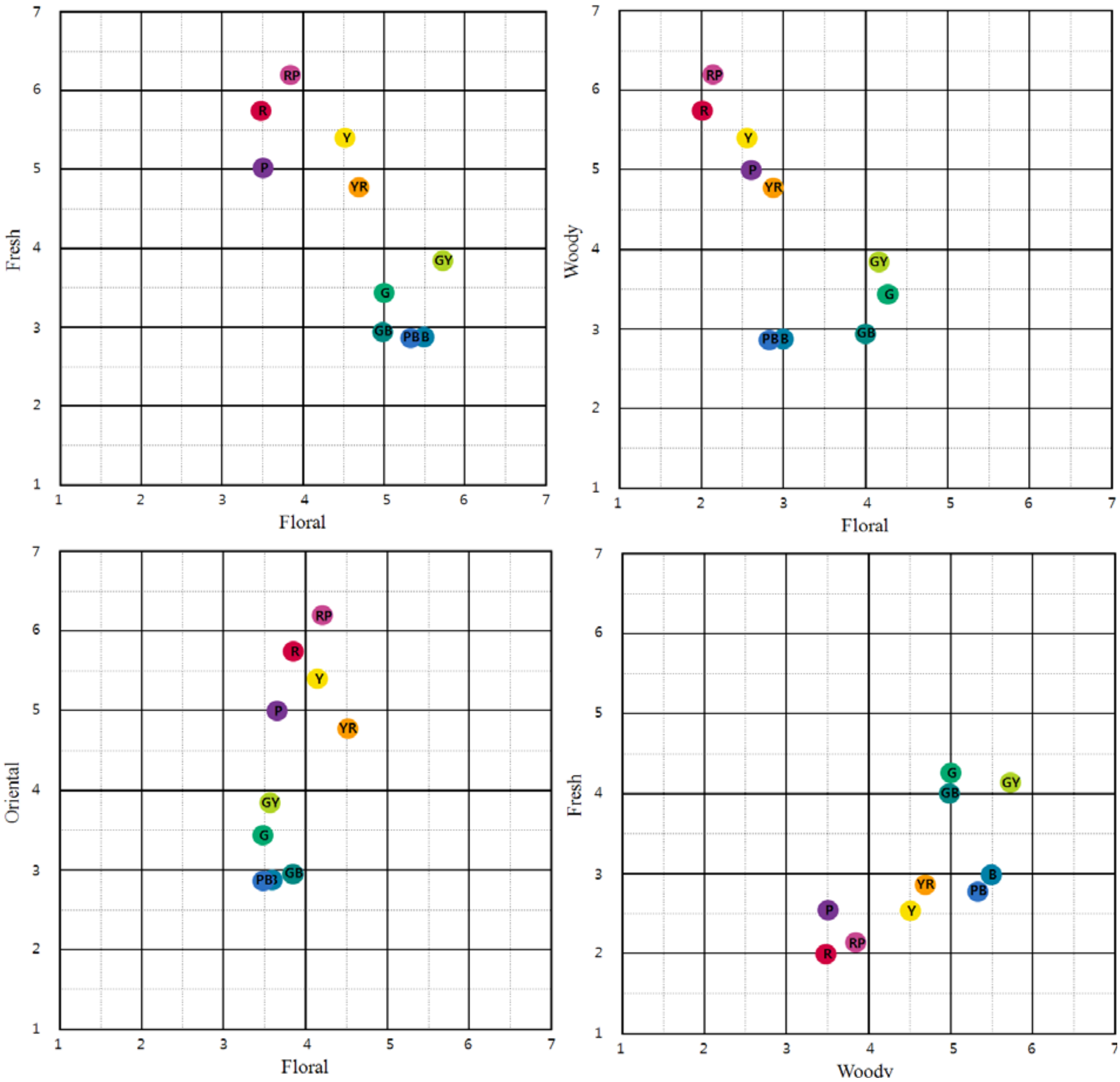

Figure 5. Two-dimensional maps for the four fragrance pairs according to mean intensity ratings across the 10 hues

Considering that 4 point on the 7-point Likert scale used in the experiment meant "average" between "very strong" and "very week" intensities, the pair (4, 4) on the maps was rebased as the origin of coordinates for dividing the map into four quadrants. Interactive patterns between the intensities of the four fragrance types were identified via the distinguishable positions of their association colors. For example, in the case of the fresh-floral map, four quadrants means as followings: I quadrant (+ strong fresh, + strong floral), II (+ strong fresh, - week floral), III (- week fresh, + strong floral), and IV (- week fresh, - week floral). Table 2 categorizes the hues positioned in each quadrant of the four maps in Figure 4. These hue categorizations can help perfume designers select colors that can well-represent the scent features of mixed fragrance materials. For example, if designers want to visualize perfumes that have strong fresh notes and strong floral notes together, yellow and yellow-orange colors can be more effective to convey the perfume's right scent images.

Table 2. Hue categorizations according to the four quadrants of the maps of the four fragrance pairs

Pairs \ Quadrants	I (strong-strong)	II (strong-week)	III (week-strong)	IV (week-week)
1. Fresh-Floral	Y, YR	G, GY, GB, B, PB	R, P, RP	-
2. Fresh-Woody	GY, G, GB	Y, YR, B, PB	-	R,P, RP
3. Floral-Oriental	Y, YR, RP	-	R, P	GY, G, GB, B, PB
4. Floral-Woody	-	GY, G, GB	R, YR, Y, P, RP	B, PB

3.2 Hypothesis 2: The associated intensities of the four fragrances vary systematically with the color tones.

In order to identify the relationships between color tone and fragrance intensity, this experiment used the visual color stimuli that were categorized into three tone groups, viz. vivid, pale, and deep, together with three achromatic colors that have different degree of lightness. Figure 6 shows mean intensity values for the four fragrances across the three tones.

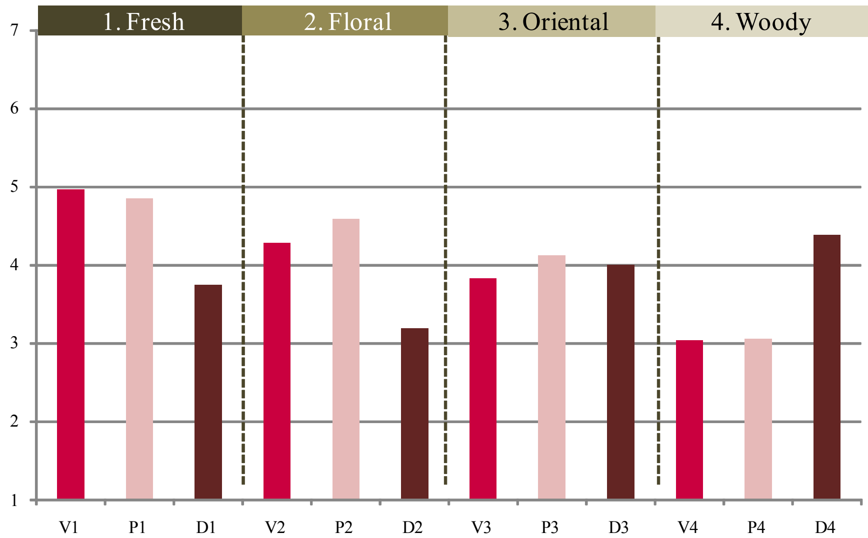

Figure 6. Mean intensity values for the four fragrances across the three tones

To assess whether the mean intensity values of the tone groups are significantly differ for each fragrance type, a series of Oneway ANOVAs were conducted. The three tones were used as the independent variables and fragrance intensity was used as a dependent variable. The Tukey test was also used to detect significant differences (at $p < 0.05$) between the tone groups. Relevant statistics are shown in Table 3. The Oneway ANOVA found significant differences in fragrance intensities across the three tones except for the oriental fragrance type.

The oriental fragrance intensities across the tones had no significant difference like those across the hues. This fact also supports that the subjects had little knowledge and experience with the oriental scents and fragrance material. Otherwise, they might associate a variety of fragrance materials for the oriental type simultaneously. In the case of fresh fragrance, the mean value of the vivid tone was the highest (vivid> pale > deep) and the Turkey test indicated that deep tone is statistically different (smaller) from the other two tones. The subjects associated stronger fresh scent from more vivid color tones. In particular, perceptual dimension of the floral fragrance intensity varied systematically with the lightness attribute of tone (pale> vivid > deep). Contrary to the fresh and floral fragrances, the dark tone was associated with the strongest woody intensity (M: 4.38). Darker colors can enhance the sense of smelling woody fragrances.

Table 3. ANOVA statistics and tone group means

	F statistic Tukey results	Group 1/ Vivid (*n*=67)	Group 2/ Pale (*n*=67)	Group 3/ Deep (*n*=67)
1. Fresh	58.624****/ 1,2 > 3	4.98	4.84	3.75
2. Floral	74.800**** 2 > 1 > 3	4.29	4.60	3.19
3. Oriental	2.449 -	3.84	4.12	4.00
4. Woody	75.020**** 3 > 1,2	3.04	3.05	4.38
Total	7.569*** 1,2 > 3	4.04	4.14	3.82

* p<.05, **p<.01, *** p<.005, ****p<.001
Group differences significant at p <.05 by the Tukey test

Together with the above analyses of the relationships between chromatic colors and fragrance intensities, this research explored whether the perceptual intensities of the four fragrance types differ across the achromatic colors that have a different degree of lightness. For each fragrance, an Onway ANOVA was performed using the three achromatic colors as independent variables and fragrance intensity as a dependent variable. In conjunction with the ANOVA, the Tukey test was conducted to determine whether the mean intensities for the achromatic colors differ at the 0.05 significance level. As shown in Table 4, the Oneway ANOVA revealed significant differences of fragrance intensities across the three achromatic colors for tall the four fragrances.

Table 4. ANOVA statistics and achromatic group means

	F statistic Tukey results	Group 1/ White (*n*=67)	Group 2/ Gray (*n*=67)	Group 3/ Blak (*n*=67)
1. Fresh	104.707****/ 1> 2 > 3	5.37	2.76	1.72
2. Floral	56.617**** 1> 2,3	4.18	2.10	1.70
3. Oriental	31.914**** 1, 3> 2	4.34	2.10	4.04
4. Woody	18.996**** 2,3 > 1	2.39	3.90	4.30
Total	37.138*** 1> 2,3	4.07	2.72	2.94

* p<.05, **p<.01, *** p<.005, ****p<.001
Group differences significant at p <.05 by the Tukey test

Figure 7 depicts the intensity differences among the three achromatic colors (white, medium gray, and black). In the case of fresh and floral fragrances, the mean value of the white was the highest (white> gray> black) and the Turkey test indicated that the white group was statistically different (bigger) from the gray and black groups. On the contrary, the woody fragrance had the lowest value in the white group. These tendencies suggest that color lightness varies with the associated fragrance intensity for the fresh and floral fragrances (positively) as well as the woody fragrance (negatively).

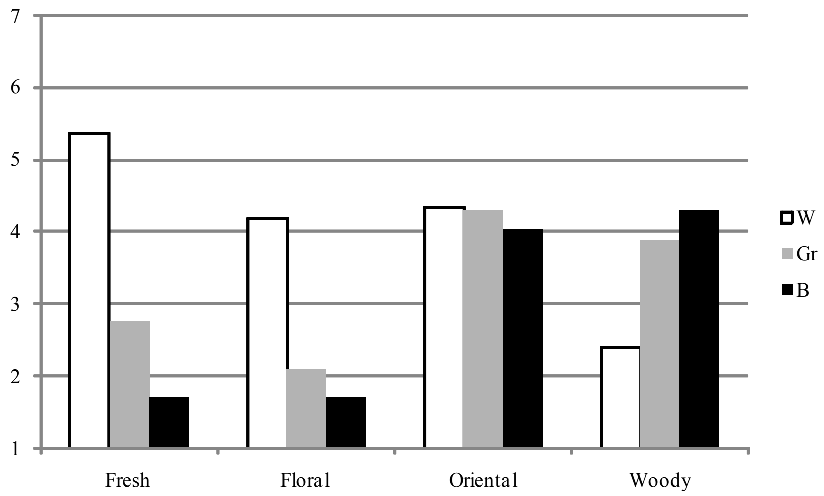

Figure 7. The mean intensity differences of the four fragrances among the three achromatic colors

4. Discussions and Conclusions

The purpose of this experiment was to examine the cross-modal relationship between color hue-tone and fragrance intensity. The results showed that associated fragrance intensity varies systematically with hue and tone of color even though it does not have a consistent pattern of variation for the all four fragrances. Among the fragrance types, the oriental fragrance showed no distinctive patterns for variations on the hue and tone of the color stimuli owing to subjects' little knowledge and experiences in the oriental fragrance materials. Besides, the floral fragrance with gender-specific perfume characteristics showed a significant gender differences in its intensity association from the colors. Moreover, interactive patterns (see Figure 5), which were discovered from the associated intensity distributions of the four fragrance types across the 10 hues, provide practical color design guidelines to designers who create appropriate color palettes for perfumes mixed with diverse types of fragrances.

Referring to the results discussed in Chapter 3, a hue-tone area that evoked the strongest intensity for each fragrance type was marked in Figure 8, except for the oriental type. For the three fragrances, their

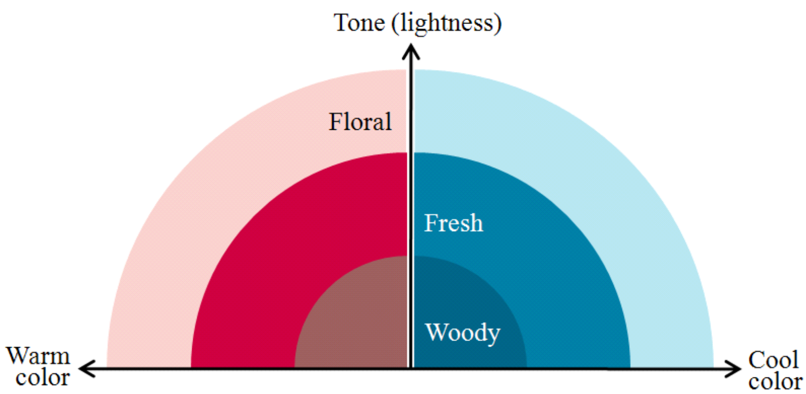

Figure 8. Hue-tone areas evoking the strongest intensities for the floral, fresh, and woody fragrances

cross-modal relationships between color and fragrance appear to be dimensional according to warm-cool image of hues and lightness attribute of tone. As colors, which are applied to commercial perfume's bottles and packaging, become warmer and brighter, the evoked floral intensity will increase while the woody intensity decreases. People tend to associate stronger fresh scents from more pure cool colors with higher saturation. Finally, this research supported that the visual color stimuli, which have hue and tone parameters, were appropriate as fragrance intensity elicitors through identifying the existence of congruent links between color and fragrance. It is hoped that this research will be beneficial for companies that want to convey the unique characteristics and fragrances of their perfumes to consumers through designing the bottles and packages in more effective and attractive ways.

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