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Practical application of browns and grays based on a vector concept—The practical strength the asymmetrical Munsell color space

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Abstract

A comparison was done regarding tertiary students' response between the symmetrical color wheel—The Itten Color Wheel developed by Johanne Itten at Bauhaus school and the asymmetrical Munsell Color Space developed by Professor Albert Munsell. One of the significant differences was the students' response on the representation of browns and grays. Students realized the Itten Color Wheel did not indicate these less chromatic browns and grays in relation to their pure hues while the Munsell Color Space arranged these browns and grays progressively in accurate vector length from one hue to another. The Munsell Color Space was first developed with watercolor paint representing the true practical range of each hue with its transitional tertiary colors, namely the intermediate browns and grays within the color space. The practical range between any two or more hues could be visualized with the help of these intermediate browns and grays. To further investigate the importance of the asymmetrical structure of the Munsell Color Space and the practical advantage through representing browns and grays in the color space, this article will present a vector approach of color planning. This approach further enhances the learning of color theory based on the Munsell Color Space. A few practical examples are also shown in this article to illustrate how this vector approach may help in learning and planning color applications.

KEYWORDS

asymmetrical, brown, color, Munsell, space

1 | BACKGROUND

There are two color theory models seen in art education and in industries respectively, namely the Itten Color System, commonly used in art education and the Munsell Color System used by many industries. To understand their difference in choice, we have to go back to the early history of color theory development. This study will focus on comparing the differences of these two models while the cultural or geographical interpretations of colors are omitted. Below are some literatures that indicate diverse definitions of colors with contextual differences. Therefore, it will not be included in structural training of colors for students.

1.1 | Diversity in cultural, symbolic, and emotional representations with colors

Cultural, symbolic and emotional representations are three major areas of application of colors connected closely to human activities besides all the practical application in the industries, education and fine art. Researchers have been exploring these areas and the major research effort is to address if there is any specific linkage that is universal between colors and certain choices our ancestors have made.

In a cross-cultural research related to the symbolic meanings of colors, the author looked into color symbolism that covered from cultural, mythical, historical, religious, political

TABLE 1 Comparing the difference in color representation between English and Chinese language, of the same subjects

English	Chinese
Black tea	Red tea (红茶)
Brown bread	Black bread (黑面包)
Green-eyed	Red-eyed (眼红)

and linguistic connections. The research data showed that ancient color symbolism largely derived its reference from nature. For example, blue would stand for the sky, and it was further connected to spirit and truth. In a case study, this point was further proven ancient human-beings translated their experience into concepts for ease of comprehension. Therefore, red means fire, white means frost and blue means sky. One important point raised was that the interpretations of color may be different for diverse cultural environments.¹

For indications of directions, the research findings above did not indicate the reasons for the choice from various cultures. However, the findings clearly indicate the subjective difference from culture to culture. Similar difference is also seen in religion; where the Buddhists use yellow as the color of humility while in Christianity, white is the color used to indicate purity. The difference also extends to different geopolitical locations, in accordance to the people and religions based on the author's study of minority tribes in China. This has confirmed that the cognition of colors and their symbolic meanings deviate from culture to culture.¹

Some examples of symbolic representation difference of color are shown. Yellow means "deceit" or "cowardice" in Northern Europe, while it carries positive meaning in Chinese culture and Buddhism, representing imperial quality and humility or renunciation respectively.¹

There are too many examples that indicate the difference of color meanings from culture to culture. The author chose three very concrete examples between English language and Chinese language as tabulated below, Table 1.¹

We understand color-cultural or color-emotional connections derived naturally through shared experiences of people at large are acceptable as simple synesthetic responses. However, any attempt to extend this to sophisticated and subtle relationship will not function well. Hence, it is not advisable to focus on formulating structural approach to teach students these topics.

1.2 | Itten color wheel and development of a two-dimensional color theory model

In light spectrum dissected by Newton's optical approach, the prism segregation of natural sunlight or white light shows its seven component rays, namely red, orange, yellow, green, blue, indigo and violet. Newton used these colors to form a

closed ring to discuss about the similarity and difference of colors.² It served as an important milestone in the development of the color wheel for color application in visual art. However, the colors he obtained from white light did not include all the neutral colors like, browns, grays, black and white. Naturalistic objects present neutral colors in huge abundance. By removing all artificially formulated colors like plastic or paint coated surfaces from our daily visual experiences, we will be left with mostly brown and gray objects. Goethe's aggressive comment about Newton's optics most likely arose from the former's natural observations of daily objects. Leonardo da Vinci, together with other renaissance painting masters were renowned for their understanding of mixing wide range of browns and grays for their illusive representation of the observed world.³

The missing connection between the Itten Color Wheel and the colors of the commonly seen substances is that, the former only showcases pure hues while the latter has a high abundance of browns and grays. On the other hand, the Munsell Color Space presents browns and grays in clear relationship to their respective pure hues. Hence, there is a need to understand how we may develop a new model by connecting the strengths of both models in art education.

Most two-dimensional models developed after the publication of Newton's Optics in 1704³ adopted a circular or a symmetrical polygonal format in circular form. Although Goethe had many opposing ideas against Newton's Optics, he also used a circular format for his color diagram as shown in Figure 1. Chromatic colors, as Goethe argued that when placed together, created optically juxtaposed results to viewers. He used a philosophical argument of how human-beings compared and read the difference between the two hues. When the difference was strong, a counter-balancing result was achieved. That he regarded as color complementary which was how different hues arriving at a state of harmony.⁵

From the above argument, it shows Goethe's consciousness about complementary contrast of colors. His color

FIGURE 1 Goethe's Color Wheel [4]

FIGURE 2 A, Runge's Color Wheel, B, Wundt's Color Wheel, C, Van Gogh's Color Wheel, D, Klee's Color Wheel, E, Itten's Color Wheel [4]

wheel had three pairs of complementary colors placed opposite to each other showing that each pair would create a maximum hue contrast. This was the early understanding of hue difference before Chevreul's discovery of simultaneous contrast.⁶ Because both Goethe's color wheel or Chevreul's simultaneous contrast led towards the belief of complementary color harmony, Itten had the same belief which he applied a physical concept to remove the subjectivity of color harmony. His physical concept was based on the argument that complementary colors in pairs could be mixed to arrive at a neutral gray color as an equilibrium state. That was how complementary colors could balance each other to arrive at color harmony. If the state of equilibrium was not reached, similarly the state of harmony was not achieved.⁷

Influenced by the concept of color harmony, the development of symmetrical two-dimensional color theory models was hinted. Models by Runge (1809), Wundt (1893), Van Gogh (1878), Klee (1924), and Itten (1961) as shown from Figure 2A-E,⁴ all adopted a similar symmetrical two-dimensional format.

Kueppers developed his model through the science of reception of light by the retina. He confirmed the primary colors of light as violet-blue [V], orange-red [O], and green [G]. He understood that colors of objects observed by human eyes were reflected light received by cones of the retina. Therefore, the colors of objects should be studied based on light. This was consistent with Newton's discovery of Newtonian Optics.

"Material Color Is Relative Material does not reveal any fixed, specific color. Its appearance instead is relative. It depends on the existing illumination."—Kueppers.⁸

He further developed a hexagonal model with basic colors that cover three primary color of light above and three secondary hues of mixing any of the three primary, forming cyan-blue [C], magenta-red [M], and yellow [Y]. He further incorporated white [W] and black [B] to include the tonal change of hues. His symmetrical and hexagonal model continued to reflect the influence of Newtonian Optics and the concept of color harmony.⁸ Similarly, Kueppers's model does not address that the true application range of each hue is different with his symmetrical hexagonal arrangement of the primary and secondary hues of light. In addition, browns and grays are omitted though black and white are included.

1.3 | Munsell color space

Munsell's model was first produced through watercolor paint pigments. Because he used pigments to coat the supporting surfaces, the model was more relevant to artists and practitioners who used pigments in painting, printing or coating, as compared to a theoretical model derived from the physics of light spectrum. Munsell was not able to find a printer that could produce mid-value colors for his atlas, so he decided to produce it with watercolor paint. Figure 3 was Munsell's earliest atlas of color which represented asymmetrical

FIGURE 3 Atlas of the Munsell Color System, ca. 1915. Accession 2188, Hagley Museum and Library [9]

performances of each hue practically. His original aim was for educational purposes; however, his model was not well-received by art educators while he was gaining good popularity in various industries. Below are some documented evidences of Munsell's shift from education to industrial applications.⁹

From Munsell's symmetrical model as shown in Figure 4, until he published his asymmetrical model in 1915, he spent a lot of efforts introducing his concept to schools since he was a drawing professor. However, his model was not welcomed by professors in the educational institutions. On the contrary, his model was well received by the textile

industry. It expanded to retailers, psychologists, engineers, graphic artists, and printers.⁹

Oswald was both a chemist and a painter. His model as shown in Figure 5B influenced a few important artists, namely Dutch painter Piet Mondrian and Bauhaus artists, Wassily Kandinsky, Walther Gropius, Joost Schmidt and Paul Klee. In addition, two American art teachers, Faber Birren and Egbert Jacobson were also influenced by him and decided to adopt to his theory.¹⁰ Birren was later an influential color theory researcher who published many papers and books in color perception.¹¹

Munsell's early color space similar to these two models as shown in Figure 5A,B, was symmetrical before he developed his final version in 1915. Philip Otto Runge (1777–1810) was thought to be the first to come up with a symmetrical three-dimensional sphere of color space. The central axis continued to be the tonal axis similar to previous single sided three-dimensional models as shown in Figure 5A,B. Runge as a Romanticist painter had strong interest in the study of colors. By arranging each hue in conjunction with tone and intensity, it led to the measurement of the difference between adjacent color patches. That suggested the birth of the final version of asymmetrical Munsell Color Space.¹² Runge's model was thought to have influenced the development of Wilhelm Oswald's double cone model.¹² Both led towards the development of the Munsell Color Space, an asymmetrical and practical model.

FIGURE 4 Munsell's Early Three-Dimensional Model, 1905 [4]

FIGURE 5 A, Runge's Three-Dimensional Model, 1810, B, Oswald's Double Cone Model, 1917 [4]

In Figure 3, the atlas was just one part of the whole Munsell Color System. The complete Munsell Book of Color covered all the hues. Each hue was shown with its derived range of tinted and shaded colors at different tones and intensities. By combining all the pages of atlas of each hue, a three-dimensional model of Munsell Color Space could be formed as shown in Figure 6, a complete asymmetrical volume. This model covered full range of paint and pigments available during Munsell's time. With pigment technology advancement, this model continued to expand over time. Therefore, the color gamut continued to expand towards perceptual color gamut. With the model, color differences could be easily compared. Any industrial application was able to use it as a reference standard. This system was therefore introduced to industries that required accurate description or measurements of colors. It was in science, business and manufacturing industry where consistent color standard was critical. National Bureau of Standards created standard and calibration for Munsell's model so that the end users had a consistent reference to carry out their measurements with.¹⁴

Today we can see a wide variety of applications of the Munsell Color System not restricted to visual art. It stretches through psychology, science, engineering, archeology, and even marketing as reference standards. The Munsell company even developed specialty tools in accordance to different industrial needs. There are discriminating arguments in

brown and dark gray items in archaeological research.¹⁵ The Munsell company created a brown color scale for consistent description of archeologists about color of stones and earth materials.¹⁶ A series of Munsell Color Charts with browns and grays were created. These charts were used as reference to compare with ceramic and stone samples for coding their colors.¹⁵

A psychological case study used the Munsell Color Space as a reference perceptual code. Stimuli were chosen from the Munsell reference chips. It established that native language affected one's perception of the world. The findings indicated that language-specific terminology could affect human color perception.¹⁷ Biological Science used the Munsell color checker charts to study animal camouflage.¹⁸

Another example was for a marketing study by an advertiser. Interestingly, this advertiser used the Munsell Color System for its study just because other influential companies used the Munsell Color System. In design industry, judgments made by artists were intuitive and personal. Gorn studied if there was any linkage between color attributes and consumers' response. He used the Munsell Color System as his standard. The reason was, this system had been widely adapted by established companies such as MacIntosh computers, Kraft cheese, and Caress soap for study of psychological research on color.¹⁹

It also credited the Munsell Color System for its ease of quantitative measurement and data analysis for marketing research. An added advantage for using the Munsell Color System was its ease of conversion between advertisers' Pantone colors and Munsell Colors.¹⁹

Munsell Color Science Laboratory also work with major museums in US, like National Gallery of Art, Washington, DC and the Museum of Modern Art, New York for spectroscopy study of artworks.²⁰

FIGURE 6 Munsell Color Tree showing colors and the respective space they occupy [13]

The Munsell Color Space has its important stand in the industries, and browns and grays are critical application components in almost all industries using color. Therefore, it is necessary to understand the issue of why browns and grays are not well represented and discussed in the current educational model that based on the Itten Color Wheel.

1.4 | An educational study of Itten color wheel and Munsell color space

A research study was carried out at the University of Illinois at Chicago, Art Education program's color curriculum to understand students' response to the Itten Color Wheel and the Munsell Color Space. Initially, students were introduced to the Itten Color Wheel. After they had understood hue, tone and intensity, they were further introduced to the three-dimensional color space with the Itten Color Sphere. The Itten Color Sphere was a derivative from the Itten Color Wheel. It evolved into a three-dimensional model to include hue, tone and intensity in one model. Either the Itten Color Wheel or the Itten Color Sphere, both carried a symmetrical structure with six prismatic colors evenly placed across a circle.²¹

After that, they were introduced to the Munsell Color Space, an asymmetrical color space. Students learnt how colors were arranged differently on the Munsell Color Space. Students then discussed their opinions between the two systems. Their feedbacks suggested that the Itten Color Wheel with six prismatic colors allowed them to grasp the relationship of pure hues quickly. However, without seeing the browns and grays, that formed a gap between the learning of pure colors and learning about the relationship of browns and grays with their pure colors. In addition, the design capacity of browns and grays could not be linked with the use of the color wheel.²¹ This indicated an important practical gap in the learning of color theory based on a symmetrical model without indicating the true practical range of colors. In addition the true practical range of each hue is also closely related to its respective browns or grays.

On the contrary, the Munsell Color Space provided the full range of browns and grays in relation to their respective pure hues. In addition, students were able to compare the difference between any two colors by looking at the vector length between the two colors on the Munsell Color Space. Because the Munsell Color System was developed with watercolor pigments, over time, the pigments technology had improved and had caused the color space to grow in size. This dynamic character has created some level of uncertainty for students' learning. However, this would not quite affect the learning needs.²¹

From the comparison study, these are the differences about students' learning responses between the Itten Color Wheel and the Munsell Color Space are listed below:

- The Itten Color Wheel with its symmetrical representation of twelve pure hues has its advantage of simplicity for the learning purpose. Students could grasp the concept immediately. The Munsell's model was an asymmetrical color tree. The complexity in visualization was harder to be absorbed conceptually since the three-dimensional structure naturally looks complicated to beginners.
- The Munsell Color System was built based on available pigments. With technological advancement in paint manufacturing, the Munsell Color System continued to grow in size, which students had doubts about how that could happen. That could be a minor issue. Students may have to update their references along with their learning.
- The Itten Color Wheel with no browns and grays presented, has created a gap in understanding pure hues in relation to their respective browns and grays.

Although we realize the issue of the symmetrical Itten Color Wheel, we need to know the history of how the Itten color system was introduced before we could introduce any appropriate amendment for our pedagogical needs. The Itten Color Wheel which was first developed at the Bauhaus school by Johanne Itten in his publication "The Element of Color,"²² has been a popular training approach for more than 100 years at many art institutions. Itten's model is such a simple and direct two-dimensional diagram that even a beginner can easily pick up the basic idea of colors and concept of complementary. Moreover, the whole Bauhausian development of modern art, modern art theory and art concepts has such a huge impact within the whole modern art history. The Itten Color Wheel therefore has its concrete stand in all art institutions against the Munsell Color System. The latter is only more popular in the industries. Therefore, the Itten Color Wheel has since led the learning of color theory at entry level. We could easily find it in many training publications too. Here are two recent graphic design training books that use it; "Design Elements—Color Fundamentals"²³ and "Understanding Color—An Introduction for Designers."²⁴ To revise and to introduce an improved system taking advantages of the Munsell Color System, we may first look at the linkage of browns and grays with their pure hues and their design relevance. We may then look into an improved while simplified version of Munsell Color System that could help beginners in the learning of color theory.

2 | THE RELEVANCE OF BROWNS AND GRAYS AND THEIR RELATION TO THE PURE HUES

Composing a colored image generally involves designing color rhythm to tell stories in sequence. The differences between color patterns allow readers to see various color

FIGURE 7 Tertiary equivalent of pure colors [25]

patterns in sequence, therefore generating sequential reading, hence forming rhythm. The rhythm of color application involves comparing hue contrast. Learning how to see and use browns and grays is one critical step towards becoming more sensitive to subtle differences between hues, and later becoming more sensitive to larger hue differences. Therefore, designing color rhythm regularly involves making good decisions to pair certain browns and grays together or pairing them with purer hues. The grays described here are not just purely neutral grays. There are some that incline towards certain hues. A black or grays are tertiary equivalence of pure blue. Their major component is blue pigment. Similarly, yellow ochre has more yellow pigment, while burnt sienna has more red pigment. In the world of browns, black maps to blue, yellow ochre to yellow and burnt sienna to red as indicated in Figure 7.²⁵

Therefore, when black and yellow ochre are mixed together, a tertiary equivalence of green, a duller version of green is formed. Similarly, by mixing black and burnt sienna, it forms a duller purple because we know that black maps to blue while burnt sienna maps to red. Because we also know that mixing black with burnt sienna a dark brown is formed, therefore we now know that a dark brown is actually a duller version of purple as shown in Figure 7. Similarly, all other browns can be mapped to their equivalences. Further derivatives are Van Dyck brown and sepia. They both carry more black pigment. Therefore, they are tertiary equivalence of bluish-purple. Likewise, raw sienna which is looking yellowish but has some greenish feel, is a tertiary greenish-yellow. This is helpful in the design of color application. We are now able to identify the tertiary counterparts of all pure hues. This enables a color designer to do sound comparisons between all hues from the purest to the most neutral.²⁵

3 | DESIGNING COLOR RHYTHM WITH TRANSITIONAL COLORS

Figure 8, a simplified version of two-dimensional Munsell Color Wheel from the three-dimensional Munsell Color Space, fully maps all the browns and grays with their pure hues. The tonal axis is removed to reduce the complexity for

beginners. These browns and grays form an inner circle indicating more subtle differences between themselves as compared to the purer hues. Therefore, these browns and grays form the transitional zone between pure hues, or we may call them transitional colors in color design. It is important to handle these transitional colors well because they control the subtler differences in color design, and hence the speed of viewers' response in the reading sequence of color patterns. That forms the storytelling power through colors.

All the more gradual transition designs are linked with careful comparisons of browns and grays since they serve as intermediate colors between purer hues. For example, if the two colors are purple and green, we may select browns between them. Therefore, burnt umber and raw umber which fall between these two pure hues are the transition colors. Color rhythm can be composed based on a good reference like Figure 8 with ease.

Simply connecting with a straight line between two distant colors on a color wheel (Figure 8) could provide us with transitional browns and grays. However, this is too elementary in color design. In actual practice, we are able to create even more complex and powerful rhythm with a vector concept like vectors in mathematics. If we could imagine between any two colors, it is like a vector displacement between them, then we could actually move from one place to another in many different ways instead of just a straight line as shown in Figure 9A,B. Both Figure 9A,B are originated from Figure 8, the Munsell Color Wheel. The vectors plotted on them indicate different color design decisions. Any selected vector direction will be intersecting with different regions of tertiary browns and grays, creating different speed of transition between any pure colors as shown in Figure 9A,B.

Figure 9A shows that infinite numbers of vector permutations can be found, moving from one color to another, passing through different browns and grays within the Munsell Color Wheel (different dotted lines). Figure 9B shows that we do not have to follow a straight line (one of the many vector approaches) in designing color rhythm, as indicated in

FIGURE 8 Two-dimensional Munsell Color Wheel with browns [26]

FIGURE 9 A, (left), B, (right) Color vectors for designing color rhythm; direct and indirect paths of transition [25]

a red color line. Instead, we can go wild into a wider area of choice, as indicated in green color lines. The final vector is still from green to orange. Therefore, this vector approach provides us with full flexibility in color rhythm design.

Common color schemes such as split complementary, triadic and tetradic systems were developed as guidelines to aid in color decision-making. The limitations of these systems have been discussed in my previous paper,²⁷ particularly because they do not take into account the fact that each hue occupies a different proportion of the color space. The asymmetry of true practical color space is not well considered with these pairing color approach. On the contrary, we can see that the vector approach serves more comprehensively without being restricted by the asymmetry of color space. It takes into account of all the subtle differences between browns and grays as well as pure hues.

4 | TRANSITIONAL COLORS IN ARTWORKS AND VECTOR CONCEPT IN COLOR APPLICATION

Below are two practical examples of artworks by Wassily Kandinsky and Andrea Derain. Both represents the two important eras of painting history, Abstraction and Fauvism respectively, where color application reached its age of glory. Transitional colors, namely different browns and grays are evident in their paintings as shown in Figures 10 and 11. These colors, as explained in the vector concept of art making, act as transitional bridges between purer hues. They are the key to designing the rhythm of colors as discussed above. In Kandinsky's painting, in Figure 10, between many of the purer hues he used different transitional browns or grays to relate the purer hues. Some browns are nearer to yellow. Some are nearer to orange and some are nearer to red or purple. There are also different types of grays that are either nearer to blue or green. Similarly, browns or grays are seen in Derain's painting in Figure 11, on the boats, on the building walls and on the river bank. From Kandinsky's painting which has a more design look to Derain's painterly painting, both have great consideration of transitional browns and grays. The earlier discussion of how the Munsell true practical model is widely accepted by industries further encores the importance of

FIGURE 10 Around the Circle by Wassily Kandinsky, oil on canvas, 38 1/8 x 57 1/2 inches (96.8 × 146 cm²), courtesy Guggenheim Museum of Art, New York [28]

training students to understand browns and grays. Two of my paintings are used below, Figures 12A and 13A are used as illustrative examples of how vector concept is shown in a painting process.

Figure 12A is a piece of my outdoor paintings done at South Bridge Road, Singapore. Because of the color vibrancy of an Indian temple, yellowish brown and dark browns act as transitional colors between the pure hues, namely, orange, orange-red, alizarin crimson, violet, and blue. Figure 12B shows the many possible vector paths that pure hues that are along the outmost ring of the color wheel can be connected. In the actual painting, Figure 12A, the connecting browns act as bridges between these pure hues. Practically, this approach holds all the pure colors firmly maintaining the presentation of one unified image, similarly to how Kandinsky and Derain compose their colors in Figures 10 and 11.

Figure 13A is another piece of my outdoor painting painted at Little India, Singapore. Because there are more pure hues in

FIGURE 11 Charing Cross Bridge, London by Andrea Derain, oil on canvas, overall: 80.3 × 100.3 cm² (31 5/8 × 39 1/2 in.), framed: 106.7 × 125.7 cm² (42 × 49 1/2 in.), courtesy National Art Gallery, Washington D.C. [29]

FIGURE 12 A, "Indian Temple at South Bridge Road, Singapore," by Woon Lam Ng, 38 cm × 28 cm, Watercolor on paper, B, Various vector permutations of how transitional browns bridge pure blue, purple, red, red-orange and orange together

521 this painting, the browns and grays are even more critical in
 522 controlling the color connections. Figure 13B illustrates the
 523 complex vector permutations of the connecting paths. Both

sample paintings show the importance through the mapping of
 relevant browns and grays and the advantage of visualizing the
 transitional bridging of pure hues with the vector concept. In
 addition, the length of the vector, similar to its mathematical
 meaning, reflects the amount of difference between the two col-
 ors connected. In practical term, it also indicates the range of
 colors can be obtained between the two colors.

FIGURE 13 A, "Shoppers at Little India, Singapore," by Woon Lam Ng, 38 cm × 53 cm, Watercolor on paper, B, Various vector permutations of how transitional browns and grays bridge blues, purples, red-orange, orange and greens together

5 | CONCLUSION

The vector approach with two-dimensional Munsell Color
 Wheel overcomes beginners' weakness in visualizing a com-
 plex three-dimensional model, while it does not remove the
 strength of having browns and grays represented. In theory,
 these complex combinations should be visualized in a color
 space akin to the Munsell Color Tree in Figure 6. Because this
 color space is three-dimensional, it is more complicated for
 beginners to visualize the intermediate colors in space. There-
 fore, the two-dimensional model acts as an entry point for
 beginners learning color theory. Mastering these complex vec-
 tor combinations requires many years of practical experience. This
 is why many old masters only develop their signature palettes
 of tertiary browns and grays after long periods of practice and
 discovery. The vector design concept of browns and grays
 allows better understanding of subtle differences between these
 neutral colors to their parent pure colors. This has one more
 practical advantage. It reflects the true vector position of each
 hue in a color space, which is asymmetrical as indicated by the
 Munsell Color Tree. Practically, beginners learning color theory
 will immediately realize that there is very little vector space to

play with within yellow, orange and red, while green occupies the largest color space. Blue and purple occupy an intermediate size of color space. This experience can be easily achieved when browns and grays are mixed according to the two-dimensional Munsell Color Wheel. Here, the practical mixing process and the two-dimensional Munsell Color Wheel connect the students' understanding of the actual three-dimensional color space. This two-dimensional Munsell Color Wheel keeps the advantage of simplicity in visualizing like the Itten Color Wheel while maintaining the relationship between pure hues and browns/grays. Hence, it serves as students' starting journey for further exploration of the comprehensive and asymmetrical color space. In addition, the vector concept provides good logistics to assist students in their research of historical and contemporary artwork color schemes. This further ease their transition from their learning of color theory to true practical situations.

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REFERENCES

- [1] Yu H-C. A cross-cultural analysis of symbolic meanings of color. *Chang Gung J Human Soc Sci*. 2014;7(1):49–74.
- [2] Sepper DL. Goethe Contra Newton. UK: Cambridge University Press; 1998.
- [3] Shapiro AE. Artists' colors and Newton's colors. *Hist Sci Soc*. 1994;85(4):600–630.
- [4] Gerritsen F. Evolution in color. Pennsylvania, USA: Schiffer Publishing; 1988.
- [5] Goethe JWV. Theory of Colours. Mineola, New York: Dover Publications; 1840.
- [6] Roque G. Chevreul and impressionism: A reappraisal. *Art Bull*. 1996;78(1):26.
- [7] Ballard L, Itten J. Reviewed work(s): The art of color by Johannes Itten. *J Aesth Art Critic*. 1964;22(3):344.
- [8] Kueppers H. The Basic Law of Color Theory: Barrons Educational Series Incorporated. 1982.
- [9] Blaszczyk RL. The Color Revolution. 1st ed. MIT: The MIT Press; 2012.
- [10] Bernstein R. Wilhelm Ostwald and the Science of Art. Vol. 39. The MIT Press; 2006:418–419.
- [11] Birren F. Color Perception in Art. PA: Schiffer Publishing; 1986.
- [12] Marcus G. A color system for artists. *Leonardo*. 1976;9:48–51.
- [13] Munsell.com. Secondary 2017. Available at: <http://munsell.com/color-blog/color-tree/>.
- [14] Chapanis A. Color names for color space. *American Scientist*. 1965;53(3):327–346.
- [15] Ogundiran AO. Ceramic spheres and regional networks in the Yoruba-Edo Region, Nigeria, 13th-19th Centuries, A.C. *J Field Archaeol*. 2001;28(1/2):27.
- [16] Munsell.com. Available at: <http://munsell.com/color-blog/brown-soil-color-chart-archaeology/>. Secondary <http://munsell.com/color-blog/brown-soil-color-chart-archaeology/>.

2017. <http://munsell.com/color-blog/brown-soil-color-chart-archaeology/>.
- [17] Ungerleider LG, ed. *Unconscious Effects of Language-Specific Terminology on Preattentive Color Perception*. National Academy of Sciences of the United States of America; 2009.
- [18] Stevens M, Cuthill IC. Disruptive coloration, crypsis and edge detection in early visual processing. *Proc Biol Sci*. 2006;273(1598): 2141–2147.
- [19] Gorn GJ, Chattopadhyay A, Yi T, Dahl DW. Effects of color as an executional cue in advertising: They're in the shade. *Manage Sci*. 1997;43(10): 1387–1400.
- [20] Berns RS, Taplin LA, Imai FH, Day EA, Day DC. A comparison of small-aperture and image-based spectrophotometry of paintings. *Stud Conserv*. 2005;50(4):253–266.
- [21] Gude O. Color coding. *Art J*. 1999;58(1):21–26.
- [22] Itten J. The Elements of Color. 1st ed. New York: Wiley; 1970.
- [23] Sherin A. Design Elements—Color Fundamentals. Rockport Publishers; 2012.
- [24] Holtzschue L. Understanding Color—An Introduction for Designers. 3rd ed. Wiley; 2006.
- [25] Ng WL. Practical Applications of Color Theory and Design Concepts. 1st ed. Singapore: Ng Woon Lam; 2016.
- [26] Munsell AH, Farnum RB. A Color Notation: An Illustrated System Defining All Colors and Their Relations. 9th ed., Maryland, USA: Kessinger Publishing; 1941.
- [27] Zulaika E, Wahyurini O, Sayatman W, ed. *A New Approach for The Teaching of Practical Color Theory. ICCI 2015 International Conference on Creative Industry*; ITS Press; 2015.
- [28] Kandinsky W. Around the Circle, 1940.
- [29] Derain A. Charing Cross Bridge, London, 1906.

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