the color-deficient observer. The Japanese ophthalmologist Ishihara published in 1917 the first edition of a set of plates that included vanishing and transformation plates, as well as hidden plates, in which the color defective can see a digit that is camouflaged for the normal by random color variation. Another design is the diagnostic or classification plate which is a more sophisticated version of the vanishing design plate that allows for differentiating between the type of red-green color deficiency, i.e., protan or deutan. The Ishihara plates are not designed for examining yellow-blue deficiencies, i.e., tritan deficiency. In 1954, the AO-HRR (American Optical – Hardy, Rand, and Rittler) plates were printed and comprise both screening and diagnostic plates for tritan defects, as well as diagnostic and grading plates for protan and deutan defects. The plates have vanishing designs containing geometric shapes (circle, cross, and triangle) that are printed in neutral colors on a background matrix of gray dots. The saturation of the neutral colors increases in successive plates to produce designs with progressively larger color difference steps identifying different levels of deficiency.

The Ishihara and the AO-HRR pseudoisochromatic plates are often used together because their functions are complementary. The Ishihara plates are used for screening for red-green color deficiency and the AO-HRR plates to confirm protan/deutan classification, estimate the severity of red-green deficiency, and identify tritans.

Some pseudoisochromatic tests have designs containing shapes or "pathways" for the examination of nonverbal subjects and young children.

Administration of Pseudoisochromatic Plates

The majority of pseudoisochromatic tests have been designed to be viewed at 60–70 cms and standardized for natural daylight illumination (or for CIE standard illuminant C). The examiner turns the pages and controls the viewing time. An introductory plate is often included to demonstrate the visual task.

Examples of Pseudoisochromatic Plates

A number of other pseudoisochromatic tests have been produced, but none have been used as widely as the Ishihara and the AO-HRR plates. Tests have been published in Japan, e.g., the Ohkuma plates (1973), Tokyo Medical College test (1957), and Standard Pseudoisochromatic Plates (1st and 2nd editions) and in the USA, e.g., the Dvorine plates; in Germany, e.g., the Velhagen-Broschmann plates (29th edition published in 1992); in Sweden, e.g., the Bostrom-Kugelberg plates (1972); and in France, e.g., the Lanthony Tritan Album, among many others. Despite many contenders, the pseudoisochromatic plates of Ishihara remain today the dominant instrument for routine screening of color vision.

Cross-References

► CIE Standard Illuminants and Sources
► Color Categorization and Naming in Inherited Color Vision Deficiencies
► Spectral Luminous Efficiency

Psychological Color Effects

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Synonyms

Emotional color effects; Perceptual color effects

Definition

Psychological color effects are the outcome of color sensations as determined by human perception and emotion, including color influences on feelings, thinking, and behavior.

Introduction and Classification

Colors may alter people's percepts and may affect how they feel. Colors with their psychological effects are most studied under three main areas: advancing and receding/retreating colors, in relation to temperature (warm vs. cool) and in relation to emotions. Advancing and receding/retreating colors are related with visual perception where people tend to see some colors as if they are closer than they actually are or vice versa. The effect of color on warmth perception is related with feeling warm, which could be a physical or sensorial effect. In this case, some colors may increase or decrease the feeling of warmth, although the actual physical temperature remains the same. In relation to emotion, people's emotions may alter when they are exposed to different colors. There may be even more ways that colors may effect percepts and emotions, but the most studied three topics will be expanded in this overview.

Advancing and Receding/Retreating Colors

Colors in Isolation

In studies treating colors in isolation, Luckiesh provided one of the earliest arguments on the "retiring" and "advancing" effects of color letters placed in the same plane [1]. In 1918, he used an apparatus with red and blue filters "of fairly high purity" with which he altered the color of the letters *X* and *E* viewed inside wooden boxes. The subjects moved the red *X* until it appeared to lie in the same plane as the blue *E*. He found a lot of inter-subject variability, but still in most of the cases it was necessary to move the red *X* further away in order to make it appear to be in the same plane with the blue *E* [1, also cited in 2]. One explanation on the advancing quality of red comes from the operational mechanism of the eye. The lens of the eye has to adjust to focus the red light wavelengths, as their natural focal point lies behind the retina. Thus, red advances, creating the illusion that red objects are closer than they actually are [3]. This phenomenon is about the monocular depth perception of the eye where shortwave light refracts in the eye's optical media more than longwave light; thus, the equidistant sources of different colors cannot be simultaneously focused on the retina, which is also called chromatic aberration [4].

Successive studies on the advancing property of color found instances when blue was judged to be "nearer" than red. Pillsbury and Schaefer, in 1937, had subjects view either red neon or blue neon and argon lights [5]. When the lights were placed equidistantly, the blue light was judged the nearer. The explanation for this "conflict" in apparent nearness of red vs. blue is explained by subsequent research that suggests lightness (or brightness) to be the controlling quantity for apparent distance [2]. The Purkinje shift, a well-known physiological phenomenon, demonstrates that blue light appears lighter than red at low luminance levels.

Colors in Combination

In studies with color combinations, the relationship between perceived colors, e.g., contrast, becomes important. Mount et al. conducted the first outdoor research of color distance in 1956 [6]. They mounted four chromatic (yellow, green, red, blue) and four gray papers on plywood. The plywood with chromatic colors and grays attached on it was viewed outdoors against a dirt bank under full sun. Participants compared a chromatic color or a gray against a dark or light gray standard on each trial. It was found that each chromatic color was judged to be closer than its nearest matching gray. Each of the hues and the grays appeared closer when viewed against a dark standard rather than the light one. They found no difference in advancement for one hue over another. On the other hand, as saturation of a color was increased with respect to its background, its apparent position advanced (an effect equal at most to 1.5 % of the standard distance). Colors having high lightness contrast with their background appeared advancing (an effect equal at most 3 % of the standard distance). Thus, increasing relative contrast by increasing an object's lightness and/or saturation as compared to its background makes the object appear closer [2].

These findings are supported by the 1960 study of Oyama and Nanri [7]. They had participants compare standard and variable circular shapes in all combinations of achromatic and chromatic relations on varying backgrounds under laboratory conditions. They found that the apparent size of the figure increased as its lightness increased, while the lightness of the background decreased. They found no effect of hue on apparent size [2, 7].

Egusa confirmed the findings of the studies above [8]. In 1983 he found an effect of hue when hemifields of different hues were compared for perceived depth. The green-blue difference in perceived depth was smaller than the red-green difference, with red appearing nearer. He also noted that a higher saturated color was judged nearer when it was red or green, but there was no such effect for the blue [8].

In the studies above, it appears that there may be a combined effect of all attributes of color, hue, saturation, and lightness, on advancing or receding/retreating colors, especially when they are viewed in combination. Lightness seems to be the most dominant attribute. Colors having high lightness contrast with their backgrounds appear advancing. Saturation seems to be the second most important attribute of color in judgments of nearness. As saturation of a color increases with respect to its background, it seems closer in the visual field [2].

In Relation to Temperature (Warm/Cool)

The definition of warm is directly associated with color as "having the color or tone of something that imparts heat, specifically of a hue in the range yellow through orange to red" [9]. Warmth perception is a multisensory experience of the immediate environment including physical (e.g., thermal properties, surface properties, etc.) and sensory (e.g., visual, tactile, olfactory, etc.) aspects.

Color in Relation to Physical Aspects (Perceived Temperature) of Warmth

Hue affects warmth perception independent from saturation and lightness [10, 11]. Although no relationship was found between colored illumination and perceived temperature [12], the following studies establish a relationship between applied hue (as in wall finishing colors) and perceived temperature. Itten's study reports that in a blue-green room, participants felt cold at 15 °C, whereas they felt cold at 11.1 °C in a red-orange room [13]. In 1976 Porter and Mikellides found that occupants preferred 2.2° higher indoor environment temperature in a blue room than in a red room. Occupants felt cold at 22.2 °C in a blue room, while this temperature was preferable in a red room. In a red room, they felt warm at 24 °C [14].

Color in Relation to Sensory Aspects of Warmth (Warm Colors vs. Cool Colors)

Warm colors are perceived warmer than cool colors [11, 15]. In interiors, one study reports that red and yellow induce the perception of warmth, while white is regarded as the coolest color [16]. In applied surface colors, hue influences warmth perception, where warm colors (red, orange, yellow) are regarded as being warmer than cool colors (green, blue, purple).

In a study on "nasal thermal sensation," participants felt cold in their nasal nostril when smelling green-colored water and felt warm in their nasal nostril while smelling red-colored water. Thus, the visual sense affects the warmth perception of the olfactory sense as well [17].

Color Emotion

Color as an effective design tool influences people's emotions in interior spaces. Red is one of the powerful colors and creates the highest number of emotional responses [18]. It is associated with surprise, happiness and sadness [19], energy, vitality and power [20], fear, and anger [21]. Thus, red evokes emotions in a range from the negative (anger, fear, and sadness) to positive (happiness, energy, power) ones [22].

Green is associated with nature and trees, which creates a feeling of comfort with a number of positive emotions such as feelings of relaxation, happiness, comfort, peace, and hope [23].

Blue is connoted with infinity and serenity in relation to the sky and the sea, representing peacefulness and relaxation [24]. Blue was found also to be associated with happiness [19], calmness, peacefulness, relaxation, modernism, coldness and dullness [25], and sadness [26].

Users usually desire colors in order to feel something or in order to create a psychological bond with an object or a space. It should also be noted that if people indicate any color as being their least favorite in their daily lives, in some instances they also associate an interior with that specific color with disgust [22].

Psychosomatic Effects of Color

Each color and color combination has its own sensation. Individually or in relation to each other, colors may become eye irritants or may cause headaches. They can effect brain waves, hearth rates, blood pressure, and respiratory rates [27]. There is an ancient and widespread faith in the healing power of color, some of which is studied under color healing or color therapy [28, 29].

Cross-References

- ▶ Anchoring Theory of Lightness
- ▶ Color Combination
- ▶ Color Contrast
- ▶ Mixed Chromatic Adaptation
- ▶ Unique Hues

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