

# Narration Script: Color Lecture (68 Slides)

Based on “color.pptx”

## Introduction

This script provides a detailed narration for each of the 68 slides in the presentation “Color.pptx”. The slides are numbered sequentially from 1 to 68.

## Slide 1: Color

### Narration:

”Let’s begin our exploration of color. This slide shows our title and introduces Phillip Otto Runge, a German Romantic painter from 1777 to 1810 who made significant contributions to color theory. His work helps us understand that color is both a scientific and artistic phenomenon.”

## Slide 2: Outline

### Narration:

”Here’s what we’ll cover today. We’ll start with the physical origin of color, then look at spectra of light sources and surfaces. We’ll examine the physiology of color vision, move to quantifying color perception, explore various color spaces, and finally discuss color constancy and white balance.”

## Slide 3: What is color?

### Narration:

”So what exactly is color? It’s crucial to understand that color is not an intrinsic property

of objects themselves. Rather, as vision scientist Stephen Palmer explains, color is a psychological property that emerges from the interaction between physical light and our visual system. Objects don't 'have' color - they reflect light that our brains interpret as color."

## **Slide 4: Electromagnetic spectrum**

### **Narration:**

"This slide shows the electromagnetic spectrum. Notice that visible light is just a tiny sliver between about 400 and 700 nanometers. Everything outside this range - from radio waves to gamma rays - is invisible to our eyes."

## **Slide 5: Human Luminance Sensitivity Function**

### **Narration:**

"Our eyes aren't equally sensitive to all wavelengths. This graph shows our luminance sensitivity function - we're most sensitive to green-yellow light around 550 nanometers. This peak sensitivity has evolutionary advantages and affects how we perceive brightness across different colors."

## **Slide 6: The Physics of Light**

### **Narration:**

"Physically, any light source can be completely described by its spectrum - the amount of energy emitted at each wavelength from 400 to 700 nm. This spectral power distribution is the raw material from which all color perception begins."

## **Slide 7: Spectra of Light Sources**

### **Narration:**

"Here are examples of different light source spectra. Notice how they vary: daylight has a relatively smooth distribution, incandescent bulbs lean toward red, fluorescents have

sharp spikes, and LEDs can have various profiles. These differences explain why colors look different under different lighting.”

## **Slide 8: Spectra of light sources**

### **Narration:**

”Another visualization from Popular Mechanics showing light source spectra. Understanding these spectral distributions is fundamental to fields like photography, display technology, and lighting design.”

## **Slide 9: Spectra of light sources**

### **Narration:**

”Here’s a more whimsical representation from xkcd. Even in simplified form, you can see how different sources emit light differently across the spectrum.”

## **Slide 10: Reflectance Spectra of Surfaces**

### **Narration:**

”Now let’s consider surfaces. Objects reflect light, and each material has a characteristic reflectance spectrum showing what percentage of light it reflects at each wavelength. This determines what color we perceive the object to be.”

## **Slide 11: Interaction of light and surfaces**

### **Narration:**

”Putting it together: The color we see is the product of the light source spectrum multiplied by the surface reflectance spectrum at each wavelength. This interaction creates the light that enters our eyes.”

## **Slide 12: Interaction of light and surfaces**

### **Narration:**

"A thought-provoking question: What color is a surface under monochromatic light? Under single-wavelength light, objects can only appear as that color, black, or white. Artist Olafur Eliasson explores this in installations like 'Room for one color,' forcing us to experience a monochromatic world."

## **Slide 13: Outline**

### **Narration:**

"Having covered the physics of light and surfaces, we now turn to the biology: the physiology of color vision."

## **Slide 14: The Eye**

### **Narration:**

"The human eye functions somewhat like a camera but is far more sophisticated. Light enters through the cornea and pupil, whose size is controlled by the iris. The lens focuses light onto the retina, where photoreceptor cells convert light into neural signals."

## **Slide 15: Rods and cones, fovea**

### **Narration:**

"The retina contains two main photoreceptor types: rods and cones. Rods handle low-light vision and detect only brightness, not color. Cones are responsible for color vision but require more light. They're densely packed in the fovea - the central 1-2 degrees of our visual field where we see with highest acuity."

## **Slide 16: Rod / cone sensitivity**

### **Narration:**

"This explains why we can't read in the dark. In low light, only our rods are active, and

they provide no color information. Our cones need sufficient light to function properly.”

## **Slide 17: Three kinds of cones**

### **Narration:**

”We have three types of cones, each sensitive to different wavelength ranges: S-cones for short wavelengths (blue), M-cones for medium (green), and L-cones for long (red). Their overlapping sensitivities allow us to perceive a full spectrum of colors.”

## **Slide 18: Physiology of Color Vision**

### **Narration:**

”The cones aren’t evenly distributed. There are roughly 10 L-cones for every 5 M-cones and 1 S-cone. Interestingly, the very center of the fovea has almost no S-cones, which is why very small blue details can be hard to see directly.”

## **Slide 19: Physiology of color vision: Fun facts**

### **Narration:**

”Some fascinating facts: The genes for M and L cone pigments are on the X chromosome, explaining why red-green color blindness is more common in men. Some women with gene variations may even be tetrachromats with four cone types. And other animals have different numbers - from one cone type in nocturnal animals to twelve in mantis shrimp!”

## **Slide 20: Color perception**

### **Narration:**

”Now we’re building toward understanding color perception. Our cones act as filters on the incoming light spectrum, each returning a single response value based on how much light it absorbs.”

**Slide 21: Color perception****Narration:**

"This means we're reducing a continuous spectrum - which contains theoretically infinite information - to just three numbers: the responses of our L, M, and S cones."

**Slide 22: Color perception****Narration:**

"We can't possibly represent an entire spectrum with just three numbers - most spectral information is lost. This compression is why different spectra can look identical to us."

**Slide 23: Color perception****Narration:**

"This leads us to an important concept: metamers. These are different physical spectra that produce the same cone responses and therefore appear as the same color to us."

**Slide 24: Color perception****Narration:**

"Metamerism is fundamental to all color reproduction technology. Your printer, your phone screen, and a painting can all create what looks like the same orange using completely different physical spectra."

**Slide 25: Metamers: Spectra that appear indistinguishable****Narration:**

"Here's a clear example of metamers. These two spectra look different when plotted but appear identical to our visual system because they stimulate our cones in exactly the same way."

## **Slide 26: Metamers: Spectra that appear indistinguishable**

### **Narration:**

"Another metamer example. This phenomenon explains why color matching can be so challenging in fields like textile manufacturing or paint mixing."

## **Slide 27: Color: Outline**

### **Narration:**

"Having understood that color is a perceptual phenomenon, how do we quantify it? That's our next topic."

## **Slide 28: Quantifying color perception**

### **Narration:**

"We can think of the human visual system as a 'black box.' Spectra go in, color sensations come out. To quantify this system, we need to perform careful human experiments."

## **Slide 29: Color matching experiments**

### **Narration:**

"Color matching experiments aim to understand which spectra produce the same color sensation. These experiments form the foundation of color science and colorimetry."

## **Slide 30: Color matching experiment 1**

### **Narration:**

"In a classic color matching setup, an observer views a test light. They have control over three primary lights - typically red, green, and blue. Their task is to adjust these primaries until the mixture matches the test light."

**Slide 31: Color matching experiment 1****Narration:**

"The observer adjusts the intensities of the red, green, and blue primaries. For many colors, this works well, and we get positive values for all three primaries."

**Slide 32: Color matching experiment 1****Narration:**

"But sometimes, no mixture of the three primaries can match the test color when all are added together. The mixture always looks desaturated compared to the test."

**Slide 33: Color matching experiment 1****Narration:**

"The solution is counterintuitive: add one of the primaries to the test light itself. Now the mixture of the remaining two primaries can match this modified test. This gives us a negative value for that primary."

**Slide 34: Color matching experiment 2****Narration:**

"Let's look at another example. Here we're trying to match a monochromatic test light at 450 nm - a blue color."

**Slide 35: Color matching experiment 2****Narration:**

"Again, we find that simply adding our RGB primaries can't match this pure blue. The mixture always looks less saturated."



## Slide 36: Color matching experiment 2

### Narration:

"By adding red to the test light, we can now match it with just green and blue. This gives us a negative value for the red primary."

## Slide 37: Color matching experiment 2

### Narration:

"The complete matching results show positive green and blue values, but a negative red value. Negative values are mathematically fine but conceptually challenging."

## Slide 38: Empirical properties of color matching

### Narration:

"A crucial finding from these experiments is that color matching is linear. If spectrum A matches mixture X, and spectrum B matches mixture Y, then  $A+B$  will match  $X+Y$ ."

## Slide 39: Color matching is linear

### Narration:

"This linearity property is enormously important. It means we can use linear algebra to model and compute color matches, which simplifies color science tremendously."

## Slide 40: Outline

### Narration:

"Using what we've learned from color matching experiments, we can now construct mathematical models called color spaces."

## Slide 41: Linear color spaces

### Narration:

"By fixing three primary lights, we define a linear color space. Any color can be repre-

sented by three coordinates - the amounts of each primary needed to match it.”

## **Slide 42: Linear color spaces**

### **Narration:**

”To find coordinates for any arbitrary color, we need matching functions. These tell us how much of each primary is needed to match monochromatic light at every wavelength.”

## **Slide 43: Linear color spaces**

### **Narration:**

”The matching functions act as filters on the target spectrum, similar to how our cone sensitivity functions work. They’re the bridge between physical spectra and color coordinates.”

## **Slide 44: Linear color spaces**

### **Narration:**

”Mathematically, we compute color coordinates by integrating the product of the spectrum and each matching function across all wavelengths.”

## **Slide 45: Matching functions act as filters**

### **Narration:**

”This emphasizes the analogy: just as our cones filter the spectrum to produce three responses, matching functions filter the spectrum to produce three color coordinates.”

## **Slide 46: Finding coordinates in a linear space**

### **Narration:**

”Here’s the mathematical process. For each primary, we multiply the spectrum by its matching function and integrate across wavelengths to get that coordinate.”

## **Slide 47: Finding coordinates in a linear space**

### **Narration:**

"This calculation gives us the tristimulus values - the three numbers that represent a color in our chosen color space."

## **Slide 48: RGB color space**

### **Narration:**

"The most familiar linear color space is RGB, based on red, green, and blue primaries. However, its matching functions have negative parts, reflecting that sometimes primaries must be added to the test light."

## **Slide 49: RGB matching functions**

### **Narration:**

"These are the actual RGB matching functions. Notice the negative lobes, particularly for the red matching function at short wavelengths."

## **Slide 50: RGB primaries**

### **Narration:**

"These are the specific RGB primaries used in the experiments that generated those matching functions."

## **Slide 51: Comparison with cone responses**

### **Narration:**

"RGB matching functions aren't identical to our cone sensitivity functions, but they're related by a linear transformation. We can convert between them using a 3x3 matrix."

## Slide 52: Linear color spaces: CIE XYZ

### Narration:

"To avoid negative values, the CIE created the XYZ color space with imaginary primaries. Its matching functions are all positive, making calculations more convenient."

## Slide 53: CIE XYZ matching functions

### Narration:

"These are the CIE 1931 XYZ matching functions. The Y function corresponds to luminance, which is why it matches our brightness sensitivity."

## Slide 54: CIE XYZ history

### Narration:

"The CIE XYZ system was developed in the late 1920s based on experiments by Wright and Guild with just 17 observers. Remarkably, this small study became the international standard for colorimetry."

## Slide 55: Uniform color spaces

### Narration:

"A problem with XYZ is that it's not perceptually uniform. Equal distances in XYZ don't correspond to equal perceived differences. McAdam's ellipses show how our sensitivity varies across color space."

## Slide 56: Nonlinear color spaces: HSV

### Narration:

"For more intuitive color manipulation, we use nonlinear spaces like HSV - Hue, Saturation, Value. This aligns better with how humans think about color and is visualized as a hexcone or cylinder."

## **Slide 57: RGB cube on its vertex**

### **Narration:**

"HSV is often depicted as the RGB cube turned on its vertex, with white at the top, black at the bottom, and spectral colors around the edge."

## **Slide 58: Outline**

### **Narration:**

"Finally, we come to one of vision's most remarkable abilities: color constancy, and its technological counterpart, white balance."

## **Slide 59: Color perception**

### **Narration:**

"Our perception isn't just about the light hitting our retinas. Our brains perform complex processing to achieve color constancy."

## **Slide 60: Color/lightness constancy**

### **Narration:**

"Color constancy is our ability to perceive stable surface colors despite changing illumination. A white paper looks white in sunlight and indoor light, even though the light reaching our eyes is physically different."

## **Slide 61: Chromatic adaptation**

### **Narration:**

"This is partly achieved through chromatic adaptation - our visual system adjusts cone sensitivities based on the prevailing light. In reddish light, our red cones become less sensitive over time."

## **Slide 62: Adapting to different brightness levels**

### **Narration:**

"We also adapt to brightness changes through pupil dilation and neural adaptation. Think of walking from bright sunlight into a dim building - initially you see little, but soon your eyes adjust."

## **Slide 63: Adapting to different color temperature**

### **Narration:**

"We adapt better to color changes in bright light than in dim light. That's why candlelit scenes still look yellow - we can't fully adapt to the color cast in such low light levels."

## **Slide 64: Checker shadow illusion**

### **Narration:**

"The famous checker shadow illusion demonstrates how strongly our brain assumes lighting conditions. Squares A and B are physically identical grays, but we perceive B as lighter because it appears to be in shadow."

## **Slide 65: Checker shadow illusion explanation**

### **Narration:**

"Our brain interprets the scene as having consistent surface properties under uneven lighting. It 'discounts' the assumed shadow to recover what it believes are the true surface colors."

## **Slide 66: What color is the dress?**

### **Narration:**

"The 2015 'dress' phenomenon showed how color perception depends on lighting assumptions. Some saw it as blue-black (assuming cool backlighting), others as white-gold (assuming warm front lighting)."

**Slide 67: This strawberry cake has no red pixels!****Narration:**

"Similarly, this strawberry image contains no red pixels, yet we see red strawberries. Our brain uses context and memory to fill in expected colors."

**Slide 68: White balance****Narration:**

"Cameras face the same challenge. White balance adjusts colors so neutrals appear neutral under any light. It's the camera's attempt at color constancy."

**Slide 69: Incorrect white balance****Narration:**

"Without proper white balance, images can have unwanted color casts. This photo looks too blue because the camera didn't compensate for the warm indoor lighting."

**Slide 70: Correct white balance****Narration:**

"With correct white balance, colors appear natural. The same scene now looks as our eyes would see it."

**Slide 71: White balance techniques****Narration:**

"White balance can be done with film (using different films or filters), digitally with automatic algorithms, presets for common lights, or custom settings using a reference object like a gray card."

## **Slide 72: White balance**

### **Narration:**

"These diagrams show the effects of different white balance settings on the same scene photographed under different lighting conditions."

## **Slide 73: White balance**

### **Narration:**

"More examples showing how white balance corrections shift colors along the blue-yellow axis to compensate for the color temperature of the light source."

## **Slide 74: Is white balance solved?**

### **Narration:**

"Is white balance a solved problem? Not quite. This photo of New College, Oxford shows how automatic white balance can sometimes fail with complex lighting."

## **Slide 75: Is white balance solved?**

### **Narration:**

"Smartphones often overcorrect dramatic skies during wildfires, turning ominous orange skies back to blue because their algorithms assume any strong color cast is wrong."

## **Slide 76: Is white balance solved?**

### **Narration:**

"Mixed lighting presents particular challenges. Should we white balance for the moon or the stones? Different reference points give different results."

## **Slide 77: Is white balance solved?**

### **Narration:**

"In scenes with multiple light sources, different regions need different white balance cor-



rections. Spatially varying white balance is an active research area.”

## **Slide 78: Spatially varying white balance**

### **Narration:**

”This research from SIGGRAPH 2008 estimates different illumination in different image regions and applies local corrections, much like our visual system does.”

## **Slide 79: Uses of color in computer vision**

### **Narration:**

”To conclude, understanding color is crucial for computer vision. It’s used in object recognition, image segmentation, computational photography, and many other applications. By studying how humans perceive color, we can build better computer vision systems.”