Color plays an essential role in how we experience the world around us, but the human eye is not enough for accurate, reliable color assessment. Image Source: Unsplash user rawpixel.com

Color is powerful. It shapes our perception of the world around us, attracting us, repelling us, warning us, soothing us. In some ways our relationships with color are deeply individual due to personal associations forged over time from our unique lived experiences. At the same time, color acts as an important cultural signifier that provides critical information based on certain universalities of perception and association.

But despite the importance of human color perception, our ability to precisely see and describe color remains limited. Biological, psychological, and environmental differences between us can result in significant variations in how we experience color. Even if two people see color in an identical way, describing it in a manner that communicates an exact shade that can be universally understood may be beyond our capabilities.

The inherent unreliability in how humans perceive and communicate color has led to the development of spectrophotometric color measurement instruments that allow us to objectively capture and share color information. The instruments now play an important part in quality control processes in a multitude of industries, allowing for unprecedented color accuracy and consistency in industrial and consumer goods. However, spectrophotometers too can vary in color perception, creating potential disparities in numerical color values. By understanding color measurement parameters, you can ensure consistency of measurement and obtain the data you need for meaningful color monitoring.

Using the same illuminant for each sample is essential to ensuring consistent color data. Image Source: Mikael Kristenson

Color Measurement Parameters

Spectrophotometric color measurement is influenced by six factors that each play a critical role in how the instrument captures color information. A change in any of these factors can alter color data, creating discrepancies between numbers obtained from two identical samples or two different instruments. The six color measurement parameters that influence inter-instrument and inter-sample agreement are:

1. **Color Scale**: When measuring the height or weight of a sample, there are two primary systems of measurement: imperial and metric. When it comes to color, however, there are a number of measurement systems due to the historical development of multiple color scales. Currently, there are five complete color scales in active use: CIE X, Y, Z; CIE Yxy; CIE L*, a*, b*; CIE L*, C*, h; and Hunter L, a, b. Each of these scales consists of three numbers, but each is unique in how those numbers are determined. As such, it is essential to use an appropriate color scale for your sample and to use the same scale every time in order to create meaningful comparisons between samples.

2. **CIE Illuminant**: Just as light variations play a role in how humans perceive color, spectrophotometric color measurement is also influenced by what type of light is used. Today, there are a number of illuminants that can be used by spectrophotometers, including A (tungsten), F02 (cool white fluorescent), C (average daylight), and D65 (noon daylight). While there are good reasons to use any one of these illuminants, you must use the same type of illuminant when determining color consistency or variation of disparate samples.

3. **CIE Standard Observer**: There are two types of standard observers available: the 1931 2 Degree and the 1964 10 Degree. While there are significant similarities between them, there

are also differences that can impact color data. As such, it is important to use the same standard observer for each sample.

4. **Instrument Geometry**: The instrument geometry you select will have a significant impact on how color data is captured, and even whether it can be captured in appropriate and meaningful ways. The primary fixed instrument geometries are directional 45°/0° or 0°/45° instruments and diffuse/8° sphere instruments. Which one you choose will depend largely on the type of sample you are working with; in some cases, it will also depend on whether you want to measure appearance or color alone.
5. **Sample Preparation**: Appropriate preparation of samples is an important part of your ability to obtain accurate color data. This is also an area where human variation can create vulnerability to measurement inconsistencies. It is thus essential to create standardized sample preparation procedures and/or to use instruments that minimize or eliminate the need for human sample preparation
6. **Sample Presentation**: Sample presentation encompasses a number of factors, including how samples are positioned, the area of sample view, the measurement pattern, and the number of readings taken for sample averaging. As with sample preparation, steps must be taken to minimize variation in sample presentation, including the use of standardized procedures or instruments that minimize or eliminate opportunities for presentation variation.

Consistency of measurement parameters will optimize your ability to compare samples at any stage of the product development or manufacturing process, giving you the data you need to move forward.

Choosing a spectrophotometer that simplifies the sample preparation process for challenging materials such as powders can minimize vulnerability to variation. Image Source: Pexels user Mareefe

Choosing the Right Spectrophotometer

Theoretically, you should be able to establish consistent color measurement parameters with any spectrophotometer designed to measure your sample type. However, there are important differences between spectrophotometers that can impact consistency. First, you must choose a spectrophotometer appropriate for your measurement needs; for example, selecting an instrument with an appropriate view area and geometry is essential for obtaining the data necessary to capture the information you need. As mentioned above, you should also choose a spectrophotometer that simplifies the color measurement process as much as possible in order to guard against variation of measurement introduced by operators. This may include instruments with integrated height measurement, automatic sample averaging, appropriate measurement patterns, or on-line instrumentsthat eliminate the need for manual sample preparation altogether. Additionally, selecting a spectrophotometer that is simple to use, designed to minimize the need for frequent calibration, and compatible with accessories designed to simplify sample preparation can decrease vulnerability to human error.

HunterLab Innovation

HunterLab has been a pioneer in spectrophotometric color measurement for over 60 years. Our commitment to innovation and technological excellence has led to the creation of a comprehensive range of portable, benchtop, and on-line instruments developed with the needs of a diverse range of industries in mind. All of our instruments are designed to be user-friendly, versatile, and reliable to give you the highest level of color measurement accuracy and precision. Contact us to learn more about our renowned spectrophotometers, customizable software packages, and world-class customer support services, and let us help you select the right tools for your needs.