Demystifying Three Key Paper Properties

Whiteness, Brightness and Shade

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Prepared by:
Xerox Corporation
Global Knowledge and Language Services
800 Phillips Road, Bldg. 0845-17S
Webster, New York 14580
USA

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Overview

The language of the paper industry has evolved from a technical environment; as such the industry has not done a good job of explaining key terms and why they are important. Xerox recognizes this gap in communication and through this document attempts to demystify three critical and often-misunderstood characteristics by which paper is commonly described – whiteness, brightness and shade. This document is written in an effort to promote a better understanding of what these characteristics mean, how they are measured and what the implications are to your finished document.

Let's start with the basic definitions:

Whiteness

Whiteness is a measurement of light reflectance across all wavelengths of light comprising the full visible spectrum.

Brightness

Brightness is a measurement of light reflectance of a specific wavelength of blue light. Simply put – brightness represents a more narrow measurement of light reflectance than whiteness.

Shade

Shade is a measurement of the color of paper. Shade is defined using a universally accepted color measurement model.

So what do these definitions really mean to you? As whiteness is measured across the entire visible spectrum, this measurement better correlates with your visual perception of the paper's appearance. Having indicated that whiteness represents a better correlation, why is there so much confusion? Why do different products have either brightness or whiteness measurements?

The simple answer is that because paper is a product with very clear aesthetic qualities, and different regions of the world have established norms based on their cultural preferences or based on the nomenclature that the paper industry in their region uses most commonly.

In North America, brightness is the most commonly referenced term used outside the industry itself. However, in Europe and other parts of the world, whiteness is the more common reference. Unfortunately, there is no correlation between a paper's brightness level and its whiteness level. They are based on different measurement systems. Shade is the third factor that impacts one's visual perception of paper. Shade is typically measured using the universally accepted CIE LAB model.

Given the complexities of how brightness, whiteness, and shade interact, our objective in this document is to clarify these characteristics and describe how they impact your perception and evaluation of the appearance of images and text on a printed page. You will take away a more in-depth understanding of paper's important attributes and practical explanations that will help you select the right type of paper for your needs.

Let's start with a more detailed explanation of each of these characteristics.

Brightness

Defining brightness

In lay terms, brightness is a measurement, on a scale of zero to 100, of the amount of light reflected from the surface of a paper. For example, a 98 bright paper reflects more light than does an 84 bright paper or a 95 bright paper. Scientifically, brightness is defined as the reflectance of blue light with a wavelength of exactly 457 nanometers (nm), 44 nm wide.

Based on both the lay and technical definitions one would expect that the brightness measurement would be sufficient to differentiate two paper products. Unfortunately, it is not that simple.

Measuring brightness

Brightness measures only the blue (short wavelengths) end of the visible spectrum and completely ignores the longer green and red wavelengths – in essence, ignoring shade. This means that two samples with identical brightness values can look very different to your eyes.

Both the Technical Association of the Pulp and Paper Industry (TAPPI) and the International Organization for Standardization (ISO) have industry standards for measuring brightness, TAPPI Standard T451 and ISO Standard 2469, respectively. While the utilization of either the TAPPI or ISO standard helps to ensure consistency in the brightness measurements indicated on product packaging or marketing materials, these standards utilize different methods of measuring reflectance within the blue spectrum. As such, these two standards cannot be correlated or used interchangeably.

Typically products manufactured in North America reference the TAPPI scale, while those from other parts of the world usually reference the ISO measurement system.

These differences in brightness measurement standards, along with the impact of shade, are the reasons why two papers with an identical brightness measurement can look visually different.

Brightness measurements in excess of 100

Earlier we indicated that brightness is measured on a scale of 0-100, with 100 being the "brightest." So why are some papers labeled as being brighter than 100?

The beginning brightness range for a base paper pulp is from 0-100, but during the papermaking process, optical brightening agents (OBAs) are frequently added to improve a paper's brightness. The function of an OBA is to reflect ultraviolet (UV) light from the light source as visible light in the blue spectral region. On very bright sheets, this can create a situation where there is more reflected visible light from the surface of the paper than the light source emits, resulting in a measurement in excess of 100.

Metamerism

When two different paper samples are viewed under the same lighting conditions, perhaps incandescent lights, you may find that they look very similar. However, if you move them to another type of lighting condition – for example fluorescent lights – they may look completely different from each other. This phenomenon is called metamerism and the two samples are considered a metameric pair. Frequent contributors to metamerism include differences in OBA levels and the choice of dyes or pigments used to achieve final shade.

This phenomenon of metamerism is something to keep in mind when selecting text and cover weights that will be collated into one printed document. If the two papers are not designed and manufactured with the same formulation, there is a chance they may be metameric pairs under different lighting conditions, resulting in a document where the papers look different.

Whiteness

In lay terms, whiteness is a measurement of light reflectance across all wavelengths of light comprising the full visible spectrum. As whiteness is measured across the entire visible spectrum, this measurement better correlates with your visual perception of the paper. As such, papers that reflect a higher percentage of blue light tend to measure the highest, while those reflecting a higher percentage of yellow light tend to yield lower measurement values.

In technical terms, whiteness is a single number index referencing the relative degree of whiteness (of near-white materials under specific lighting conditions). The index has been devised such that most people will agree that the higher the whiteness, the whiter the material.

CIE Whiteness, developed by the France-based International Commission on Illumination (also called CIE), is the most commonly used whiteness index. This index normally refers to measurements made under D65 illumination, which is a standard representation of outdoor daylight. For a perfect reflecting, non-fluorescent white material, the CIE Whiteness would be 100. Similar to the discussion of brightness measurements above 100, papers containing fluorescent additives such as Optical Brightening Agents (OBA) will also measure well above 100.

Lighting conditions, or the light source, can make a big difference in the perception of whiteness. If whiteness is achieved by adding an OBA to a dull base sheet, the paper will appear bright outdoors, but dull in indoor lighting not emitting UV light. If the paper is a white base sheet with little OBA, it may compare well indoors but look duller outdoors when compared to sheets with added OBA. Other whiteness measurement systems have been developed for indoor lighting; however, these systems are not commonly used.

As CIE Whiteness is a single number index, it can only be a guide to relative whiteness. Very high whiteness is likely to indicate a blue white sheet, but you might perceive that the sheet has an orchid or even perhaps a grey cast. Visual comparison of samples under different lighting conditions is always a good idea to understand how the whiteness has been achieved, how the samples compare in low and high levels of UV light and whether the samples appear neutral white or more tinted in comparison to other sheets.

Shade

The third characteristic that impacts one's visual perception is shade. Shade represents the subtle differences in color within the visible spectrum.

Technically, shade is an important characteristic within the definition of a paper's whiteness. Shade, particularly in color printing, can directly impact the correct look and feel of the printed images.

Differences among shades

It is commonly accepted that there are three groups of white shades: true white, cream white and blue white. Today, many papers are manufactured to a blue white shade because the blue white shade appears both brighter and whiter, and therefore more pleasing to the human eye.

A balanced (or neutral) white shade of paper, often called "true white," reflects the total color spectrum equally. A cream white shade absorbs the blues and cooler colors and will usually have a yellowish tint. A blue white shade absorbs the warmer colors and reflects more blues or cooler colors. Papers with high blue reflectance levels are often referred to as "bright white" or "high white" papers.

Shade is commonly measured based on the most universally accepted system of color measurement, known as the CIE LAB model (also known as CIE L*,a*,b*). This model is also used in other color sensitive industries. For example, when you purchase a can of paint, the color will be mixed based on an LAB formula.

Implications in paper selection

While shade is considered less important for predominantly text based color documents, there are exceptions. In book publishing, significant attention is paid to the shade of the paper and its impact on a reader's visual comfort. Therefore, most book publishing grades are either a cream white or true white shade. If your content has predominantly cool colors and text, such as blue and black, a blue white sheet gives you optimum readability and crispness. If a printing job contains mostly warm colors in the red and yellow range of the spectrum, such as skin tones, selecting a more neutral "true" white paper better enhances the text and graphics.

Within the context of the current discussion, shade is probably the most complex concept to present. This is because shade is wrapped up in the science of color, color management and color measurement systems.

Hints on selecting paper for digital printing

When considering which paper is best for a digital print project let the content and purpose of your documents act as your guide. Picking the right whiteness and shade can make the difference between its visual appeal and readability.

What matters most – whiteness, brightness or shade?

If you are buying papers for monochrome (black and white) printing and copying – you can purchase based on either whiteness or brightness. Your decision to buy based on either characteristic should be driven by your personal preference for the contrast that is created between the black toner and the white paper.

If you are buying papers for color printing – make sure you are taking shade and whiteness into consideration. With the color printing process – the interaction between the inks or toners with the shade of the paper will determine whether the images on the page appear as one would expect, (i.e., skin tones looking natural, food looking real, etc.).

More guidance on paper use – Analyze the content

Is this a black or single-color text-only document or a document with few drawings or illustrations?

For black and white or single color documents, such as direct mail pieces, invoices, a manual or booklet with line drawings, your objective is to enhance its readability with crisp text and high-contrast image clarity.

Select high white paper with a blue-white shade. This paper provides the greatest reflectance and maximum detail in the text characters and printed images.

If you are producing a long document, such as a training manual or book, where you want to insure the reader's comfort – select a true white or cream white paper to minimize eyestrain.

Does the job include color photographs, graphics such as pie charts and line graphs, color illustrations or artwork?

If it does, your next assessment should be checking the predominant color tones in the photographs, graphics or illustrations. Unless the colors heavily favor one area of the spectrum, your choice should be a balanced, "true" white sheet that reflects all colors evenly. A true white sheet will help the colored graphics and photographs "pop" off the sheet and will not interfere with or add more color to the images.

If the images are all blue-toned – perhaps photographs of the ocean or birds in flight against a blue sky, you could use a bright white (bluish-white) sheet. This type of sheet would complement and not detract from the images and the text would be crisp and clear.

If the images are reddish or yellowish in tone – desert scenes or sunsets, a sheet with greater red/yellow reflectance such as a cream white sheet would be suitable because it would enhance the images without significantly affecting the text quality.

Summary

The terms of whiteness, brightness and shade can appear on the surface as a series of complex technical terms. We have tried to define and clarify these key paper properties and describe how they impact your perception and evaluation of the paper and the printed content. We hope this makes paper selection a bit less mysterious and simpler for you.