

Color Management Concepts



Color Science Tolerances

Section 6: Where & Why Color Viewing Can Fail

Color Management Concepts

Tolerances and where color viewing goes wrong:

Delta E and What is it. (A CORE CONCEPT OF COLOR MANAGEMENT)

Why Delta E is used to describe tolerances in Color Management Science Credit: http://printwiki.org/Delta_E & https://en.wikipedia.org/wiki/Color_difference

The Brief History of Delta E or ΔE^*

The scientific community and color application industries have spent a great deal of time and resources developing methods for quantifying the visual perception of color. Even before industrial applications existed to utilize such knowledge, people explored human vision and hypothesized how color is perceived. In the later half of the twenty-first century, the Commission Internationale De L'Eclairage (International Commission on Illumination, denoted CIE) made two formal recommendations for perceptual color spaces and color difference formulas that could be utilized in industry to quantify and judge color. These color spaces became known as CIELAB and CIELUV.

What led to the creation of these two color spaces and associated color difference formulas? Its a long interesting history that began with Isaac Newton hypothesizing the origin of white light.

1931 CIE Standard Observer

In his article 50 Years of the 1931 CIE Standard Observer for Colorimetry, William David Wright states "I would personally credit Dr. L.T. Troland, a brilliant American scientist of wide ranging interests, with the conception of the 1931 Observer." These words of honor were bestowed on Troland due to his work with the Colorimetry Committee of the Optical Society of America. In 1922 the committee published a report on colorimetry that included information on naming and terminology, psychophysical data, and standards and methods of colorimetry. The report also included a data table containing Average Normal Visibility Values which were standard values utilized by the American Illuminating Engineering Society. A few years later, the CIE recommended a standard visibility curve (V_λ). In 1926 John Guild presented A Survey of Modern Developments in Colorimetry at a conference held in London at Imperial College. In his presentation, Guild discussed the need for data that could be used to derive an average of what the human eye could see. After the conference, in the same year, the Medical Research College gave a grant to Wright to fund the development of a colorimeter and re-deter-

mination of spectral mixture curves.

The CIE formally created a committee to guide its colorimetry research agenda in 1928. The United Kingdom was assigned the secretariat and was given the task to collect and summarize all the research activity carried out between 1928 and 1931. They were to then present their compilation at the 1931 CIE meeting. The only countries to submitted contributions to the report were Czechoslovakia, the United States, and the United Kingdom. Each country having their own agenda. In September of 1931, the CIE Colorimetry Committee submitted their data set to the CIE for approval as standard. This data became known as the 1931 Standard Observer. With the standardization of the Standard Observer, the industry now had a tool they could utilize in color specification. By 1935 the CIE promoted the use of the Standard Observer to specify the color of signal lights in the transportation industry. The International Commission on Illumination (CIE) calls their distance metric ΔE^*_{ab} (also called ΔE^* , dE^* , dE , or "Delta E") where delta is a Greek letter often used to denote difference, and E stands for Empfindung; German for "sensation".

Color Differences

With the CIE defining a Standard Observer, an industrial need emerged for the quantification of color differences. Some research was carried out that proposed using the Munsell Color System, while other research focused on using the CIE chromaticity values. The formulas were evaluated and refined over time leading to the latest CIE 2000 formulas that allow for the tolerances in human visual perception of colors. Particularly, how the eye can be more sensitive to changes in some colors over others.

So basically, Delta E can be defined thusly today:

1 Delta E is the amount of change it takes an average person to notice a difference in color.

Color Management Concepts

Tolerances and where color viewing goes wrong:

Lesson 1: Color Viewing Tolerances of Devices and Color Spaces

We know how to do this, so what's the problem?

So far we've talked about how colors in the digital imaging world are really triplets of red, green and blue values. When these three additive primaries are mixed together, we get a color – in 8 bit, any one of about 16.7 million possible colors, in 16 bit any one of about 4 billion colors. (It's worth noting that the human eye can't actually distinguish anything like this amount of different colors, it's more about avoiding banding than anything else).

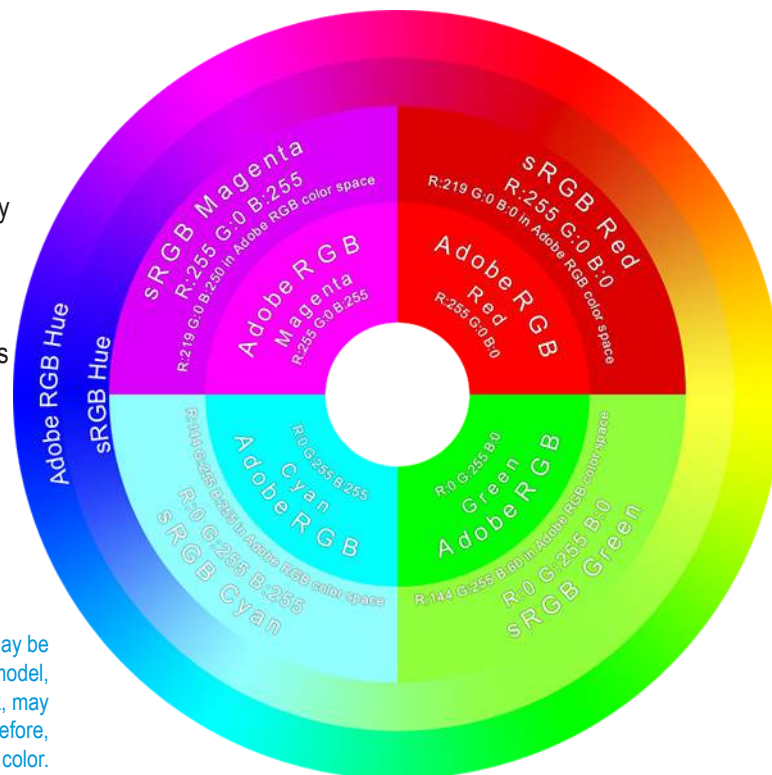
The problem is that all those numbers means different things to each different device. The thing we've glossed over until now, and it's a very big thing, is the real meaning of those numbers. At the moment they're just numbers really – nothing more. This whole section is about giving meaning to those numbers.

Just what does 255 red mean? We know it's 'our most saturated red', which is a part of the puzzle. But what is our most saturated red? Is it the monitor's most saturated red? The printer's best red? Or the camera's red? What if one day we change monitors – does that suddenly mean the colors in our photos are going to change?

It should be pretty obvious that it's no good using our devices as a reference for what a particular color number means – because they're all going to be different. Pretty dramatically different. Not only are they different types of devices different in their colors, but each device is almost certain to change its color output over time as the device ages, or ink formulations change, or whatever. Even devices of the same brand, bought on the same day, will have different color outputs – due to manufacturing tolerances.

So what do we do? Well, just like the situation with color above, where we defined standard light sources and standard observers, we're going to create some standards for what colors are. These are absolute standards for color that have nothing to do with devices. Once we've got some definite idea of what we're talking about when we talk about specific colors, perhaps we've got a chance of convincing our devices produce those colors. But without care, understanding of the devices, and management of them over time, we don't really have a chance.

Over the next few pages, we will see where the assumptions and limitations of devices can, and often do, throw off our ability to keep color consistent.



Example of sRGB vs. the Adobe RGB color spaces and how they may be visually compared. All RGB color spaces work on the same color model, but the Red, Green and Blue points, as well as the White and Black, may be different numbers in absolute color values in Lab color and therefore, appear different, even though they are all RGB device color.

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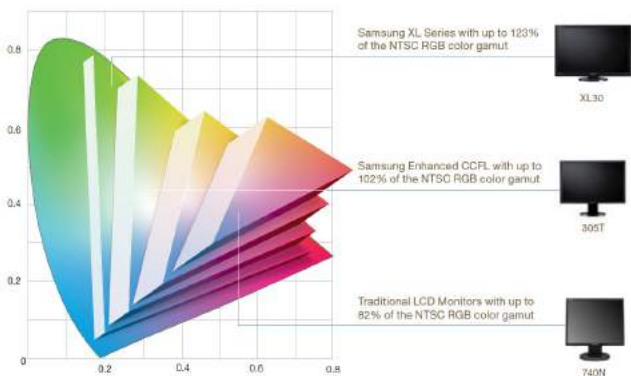
Tolerances and where color viewing goes wrong:

Lesson 2: Why you can't trust your Computer Monitor, Smart Phone or Tablet

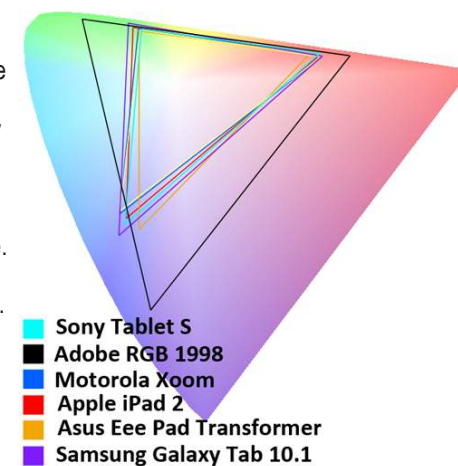
What's the Problem?



All computer monitors can show you images based on the RGB phosphors they are manufactured for showing color. Each manufacturer has components that make up that monitor based on the materials they use to create the screen. While there are standards for looking at these screens, like sRGB, NTSC or Rec 709 for HD television, the manufacturers often do not exactly hit that specification. Also, they will often build in some level of color management which can further confuse color fidelity or, in the case of a computer, the operating system can drastically affect the color representation. In fact, it is nearly impossible to calibrate two computer monitors to look identical in every situation, even from the same manufacturer. Try it sometime and you'll be surprised how hard it is. 97% of all consumer computer monitors cannot even maintain color consistency across their own screen.



Most smart phone and tablet computers are pretty fixed to the type of operating system and flat-screen manufacturer they use. Some simple color management, but its very basic. One of the bigger problems comes with the fact that these are mobile devices. Have you ever tried to use one in broad daylight with the glare on the screen? Colors look washed out and contrast is almost non-existent. The screen did not change color, but your viewing conditions changed drastically. On top of this, you have the same issues that you have with computer monitors. There are many manufactures of these devices, and they all contract with other manufactures to make their screens, and sometimes the operating software is done by someone else as well. This all leads to a huge amount of color ambiguity and no one should ever rely on one of these devices for approving color images. If you really want to push it, hold your device tightly and tip it over about 45 degrees and see if the color looks the same. I'll bet you never realized how much your viewing angle messes with color perception.



A Comparison of Some of the Tablet Device Screens

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Tolerances and where color viewing goes wrong:

Lesson 3: Why you can't trust your Ink-jet printer.

What's the Problem?



All those Ink-jet Cartridges

Typically, an ink-jet printer has ink cartridges for Cyan, Magenta, Yellow and Black (the process colors), and also includes a Light Magenta, Light Cyan and maybe a Light Black or Photo Black cartridge as well. The “light” inks are included to reduce banding and make your color prints look smoother to the eye. They do not make more colors reproducible or increase the printers gamut.

All the work of converting your documents to print out correctly is done under the hood. For the most part, you don't have much control over what its doing to convert

the on screen colors into a physical color print. In some systems, the computer's Operating System (Color Management Module - CMM for short) controls how this happens without you having to worry about it much. It's all called “pleasing color”. In other words, nothing really exact, we just expect you to be happy with it. And never mind what happens when you add different paper stocks to the mix!

If your a professional, expecting consistent and reproducible color over weeks and months, you'll have to go through the additional steps of buying some color management software, plugging in good ICC profiles and checking your calibrations, buying quality papers and keeping your inks from the same manufacturer. All these things have to happen before you have a chance at getting accurate color reproduction. Translation - \$\$.

But here's a little problem that the ink-jet manufacturers don't want to talk about, and that's in all those ink-jet cartridges that cost a small fortune. For each ink-jet cartridge you have, there's a color tolerance. The color will be extremely close, but probably not exactly the same as the previous one you put in a few months back. Now multiply that by the number of cartridges you have.

“If your printer has 6 to 12 cartridges, you might be 6 to 12 delta E off from your original calibration. And the funny thing is, the less you keep it calibrated, the more it will be off over time.”

So next time you get that “Replace Ink-jet Cartridge” message, think about checking that color calibration.

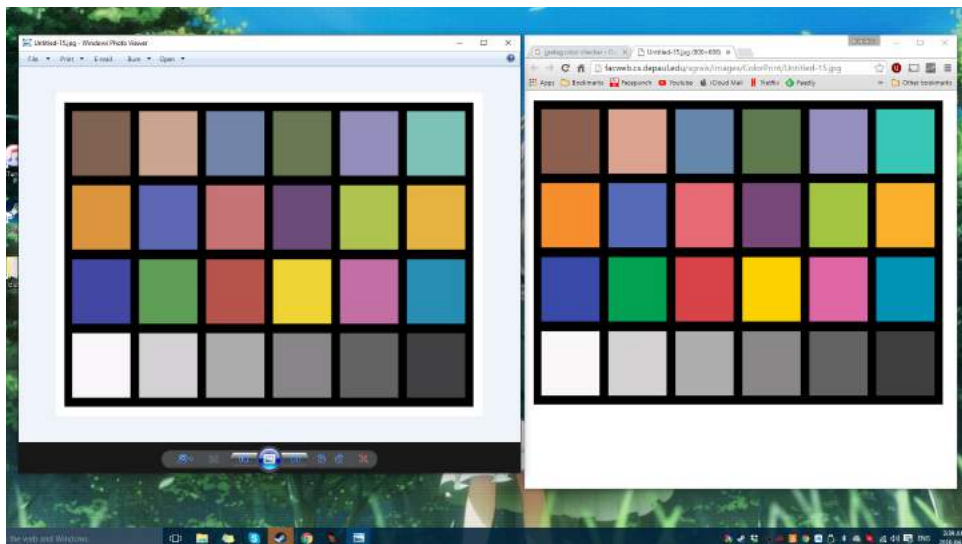


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Tolerances and where color viewing goes wrong:

Lesson 4: Why you can't trust color from some of your favorite programs.

What's the Problem?



If you look carefully at the two images of the test target, you will notice that the colors are somewhat different, some are pretty close, while others are quite a bit off. So why would this happen on the same computer monitor?

Is Color Management Built In?

Color Management is not always built into programs that are used everyday. Even though you may have calibrated your monitor, setup ICC profiles for your favorite workflows and are using good viewing conditions, on screen programs can display colors very differently. The fact of the matter is that not all programs are created equal in how they display colors.

Differences in Honoring Color Standards

Most graphics applications worth their salt will allow you to control the color environment with industry standard ICC profiles that come with them, or allow you to add in your own profiles if you have created them. This becomes a large time saver when doing color critical work. But other programs, like office suites, web browsers or database software, have little clue or idea on how to be really color accurate, nor will they read the color profile information that a file might be tagged with. If your using a paint program or drawing application that does not have a color management setup section, find another one that does.

Web Browsers

Web browsers are not ICC color compliant, they only offer you pleasing color in an assumed sRGB color space. That's simply the world they grew up in. Its not their fault, they just don't seem to know any better.

Office Programs

Office programs don't seem to have any understanding of color as well. I have even gone around with Microsoft on what CMYK really is, and how they have completely screwed up the whole CMYK color concept in their office programs, that frankly, get used for printing purposes all the time. Microsoft can't even seem to understand that black should only be black, and not some mix of RGB or rich black color that their office programs constantly mess up.

Operating Systems

Operating Systems all have some sort of underlying Color Management level, but Apple has the most mature model by far and seems to get that color can be very critical. It can be done on the other OS's, but it quite a bit more difficult, and the underlying Color Management Modules (CMMs) are not implemented nearly as well.

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Tolerances and where color viewing goes wrong:

Lesson 5: Why you have to Manage your Equipment and Processes Regularly.

What's the Problem?

All devices have a tolerance that they work within. In Color Management, the tolerance is communicated as Delta E or ΔE . With good equipment, tolerances can be kept to a minimum, and with careful tracking and checking, the devices in any workflow can be checked to see how much they vary, or conversely, how consistent they are. A Color Management Technician needs to keep track of all the devices in the color chain so that when one of them gets to far away from its specification, steps are taken to bring it back into compliance.

The Spectral/Color Reader

This is by are the most critical devices in the workflow to keep within specification. Often, the Spectrophotometer is purchased and used for several years without question. These devices often have a self calibration step they go through, but every device will start to move over time in how it reads color. This is mostly due to the illumination the device uses to read the colors. They will have guidelines on how to send them back to the manufacturer for recalibration and recertification. Generally, this happens between every 3 to 5 years. Don't forget that standards get updated, Spectrophotometers get better and sometimes the engineering is updated as well for older devices to make them more reliable, so its a good thing to send the color spectrometer in for service when its time.

Input Devices and Materials

This is often the first step in the color chain. If raw materials and raw data are not color compliant, you may want to build in a step to check compliance to in house standards before the next steps are affected. Sometime this is a simple conform to an ICC profile, or as sophisticated and having a photospectrometer check color, opacity and refractiveness. If color is critical, test steps for input/raw materials is critical too.



Operating Systems

Upgrade OS's when the latest revision is deemed stable and supports the software/hardware requirements of your company. Major releases often offer new Color Management support and capabilities.

ICC Programs and Profiles

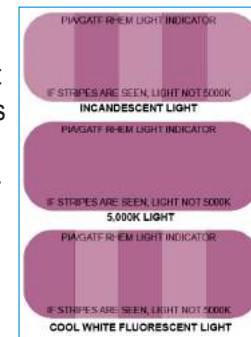
Standards do get updated based on user and industry experience. Software is written to take advantage of the new standards and ICC profiles do change over time in what they can measure and adjust. For these reasons, keep your software and ICC profiles up to date. Adjust your internal standards to reflect the latest information and keep your profiles updated.

Viewing Devices

All physical viewing devices will have bulbs that age. Most good color booths have hour trackers that automatically tell you when you need to change out for new bulbs. There are also metamerism cards to help guide you to the optimal lighting conditions for viewing color. All LED monitors have a lifespan because of the same reasons.

Plotters & Printers

Print and Plotter heads will have a lifespan. On most devices, there are optional maintenance plans or service options for keeping the device running correctly. Most service contract will not go beyond the lifespan of that average device. It is a good practice to lease plotters and printers with full maintenance plans in place for the lifespan of the lease and replace them with the latest model when the lease expires. This will keep your downtime to a minimum.



RHEM Metamerism Indicator

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Tolerances and where color viewing goes wrong:

Lesson 6: Lighting and Metamerism

What's the Problem?

When an item is viewed, the color we see is a result of the color quality of the light source and the reflective characteristics of the item. As a result, when attempting to achieve an accurate color match, colors can appear to match under one light source and then appear significantly different under another light source. Therefore, designers, brand owners, and production staff should all evaluate a color under a consistent light source. To help achieve this goal industries have developed international standards for the viewing of color.



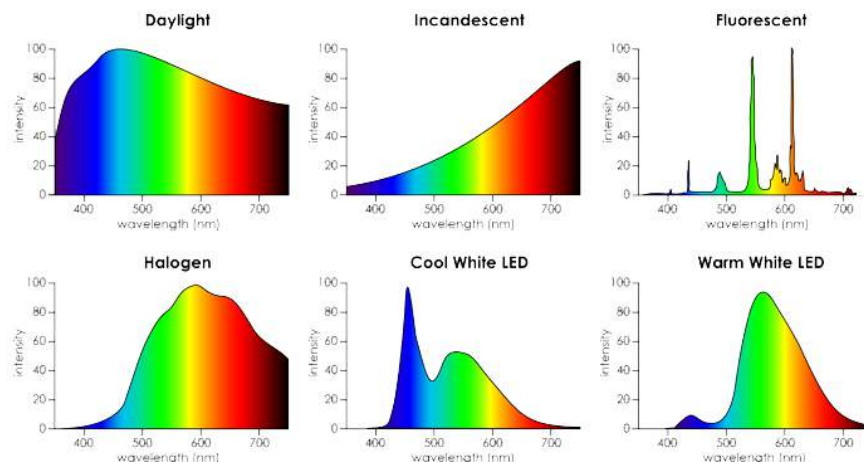
Viewing Standards

The graphic arts and photographic industries have adopted ISO 3664:2009 entitled "Graphic technology and photography— Viewing conditions." ISO 3664: 2009 specifies D50 daylight viewing conditions. Industrial color applications (plastics, paints, textiles, automotive, etc.) have adopted ASTM D1729-2009 as their standard, which specifies D65 daylight viewing conditions.

Both standards require that viewing conditions meet strict specifications with regard to color quality, light intensity, evenness of illumination, viewing/illumination geometry, and surround conditions. Differences in any of these conditions can affect color appearance.

So isn't a Light Bulb a Light Bulb?

As you can see from the viewing booths on the left, lights can vary quite a bit in the color spectrum they put out, the temperature of the light, and the overall illumination. Even the housing the light bulbs sit within can affect the quality of the light in terms of it's focus and the amount of light it emits from of the housing.



Above: Spectral output of six types of light sources.

From the illustrations, one can easily deduce that the bulb used to illuminate an area can effect the light in the environment. Even if the amount of illumination is perceived with a similar and consistent brightness, fluorescent lights can reflect light off of surfaces very differently from an incandescent bulb. As a result, the color may seem to change when walking from room to room when holding a color reference sample. This change in color from inconsistent lighting is called metamerism, and if your not aware of it, it can give you a very bad day.

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Tolerances and where color viewing goes wrong:

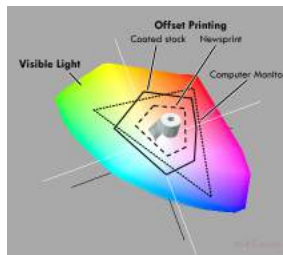
Lesson 7: Color from the physical world into Color Workflows is called “Rendering Intent”. It controls how color definitions are moved around.

What are Rendering Intents?

When using ICC Color Management aware software applications, such as Adobe Photoshop, Lightroom, or a RIP, you will frequently come across the term Rendering Intent. But what does it mean? This will hopefully give you a better idea of what Rendering Intents are, and more importantly, which one to use.

ICC profiles usually contain four Rendering Intents. These define how the color reproduction process should cope with colors and tones which are outside of, or near the edge of the device's color space, in order to achieve the desired color 'rendering'.

When reproducing color using a medium (paper and ink) with a smaller or different shaped color gamut than the original photograph or scene, it is inevitable that some colors or tones may be lost or change. These are said to be 'out-of-gamut'. The subtle tones, particularly saturated colors and dark shadows, may be squashed, flattened together or 'clipped'. This applies to the tonal range, or density, as well as to color hue and saturation. An extreme case would be a color transparency, which is designed to be viewed by transmitted light, compared to being reproduced in a newspaper with its dull 'gray' paper, and weak ink strength. Clearly, compromises have to be made. The Rendering Intents do this, but in subtly different ways.



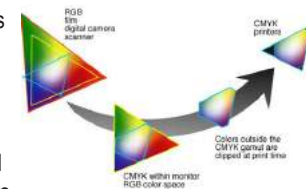
The four ICC Rendering Intents are:

Absolute Colorimetric: This Intent should be used in 'hard proofing' situations only. When proofing we typically have a larger color gamut in the proofer than in the printing press we are simulating. So out of gamut colors are seldom a problem. This will simulate the paper 'lightness' and color, if necessary, by adding a 'tint' of that color. If the printed paper you are trying to simulate is a 'dull yellow' and the proofing stock is a 'very bright blueish white', it will print a very light tint of yellow in the 'white paper' background, and also throughout the image's tonal-range. Although being very accurate colorimetrically, some customers may question the appearance of the 'paper tint'. It will also do absolutely no compression in the dark tones/colors. I would not advise using this Intent for reproducing camera or scanned images as they will probably reproduce too 'flat' with very dark highlights. So for proofing only.

Relative Colorimetric: This will map the white point of the image 'relative' to that of the original. The white point of the original color space ('Working Space') will be matched to that of the output (typically a printer

profile) and other colors scaled in relation. It can be used in proofing situations where accurate reproduction of the printing press 'paper white' isn't required. It is often used with digital camera images or reflection copy scanned images. In which case, always use Black Point Compensation ('BPC'), if available. Although it is not as accurate as 'Absolute', Relative Rendering, it can be used in 'proofing' workflows.

Perceptual: Also sometimes known as 'Photographic', it renders colors in a way which is natural to human vision. The gamut of the source image color space (typically a 'Working Space' or scanner profile) is scaled to the output color space (usually a printer profile). This will pull out of gamut colors into gamut. Colors at or near the edge of the gamut will also be pulled in to give a distinction between them. This will generally give a pleasing result. Different ICC-profiling software vendors may achieve different results with the Perceptual intent. In particular, profiles generated with older software versions may exhibit a lack of saturation. Perceptual should usually be used for color transparencies, and often also gives the best results for scans from color prints.



Saturation: This will pull saturated colors out to the edge of the gamut, thereby increasing saturation, or color 'strength'. It is intended to be used for vector graphics; i.e. logos, line-art, etc. Never use it for photographs (except special effects) or proofing!

Also Note:

Black Point Compensation: In Photoshop this is found under Color Settings, and under Print. It is used to automatically map the black point of an input (camera or 'Working Space' etc.) profile to that of an output (printer) profile. Typically the input color space will have a darker black point than that of the output print. If Black Point Compensation is not used, the shadow areas could be filled-in, losing detail, in the reproduction. This feature is especially useful when using the Relative Intent. It should normally be left ON. Not available in Elements, Illustrator, etc., but is always 'on' in the latest versions (at least) of Lightroom.

So what could trip up a color workflow here? Plenty!

Make sure you pick the proper Rendering Intents when setting up the steps in a Color Workflow. Great care and attention should take place whenever you move from a large color gamut to a smaller color space and do pick the best options when converting colors through the workflow. One misstep in setting up the Rendering Intent can cause huge problems matching color later on.