The Influence of Paper Brightness & Opacity on Print Quality

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Paper illuminates the printed image

Superior print quality is enabled by paper brightness and opacity, working together to provide generous and uniform illumination of the printed image.

A vital part of paper’s mission is to provide adequate and uniform illumination of the ink layers that make up the printed image. The various colors that make up white light are either transmitted or selectively absorbed as they enter the ink layers from above. Light passing through the ink enters the paper where most of it is scattered in random directions. Most of the scattered light exits the same side of the paper that it initially entered, bathing the ink on the paper’s surface in light from below like a projector illuminating a color transparency. See Figure 1.

![Figure 1](image)

How Brightness Affects Illumination

Brightness is a basic measure of the amount of light that paper makes potentially available for illumination of the printed image. Low-brightness papers absorb some of the illuminating light, causing printed colors to look “muddy” instead of bright and saturated. The most popular test for this paper attribute is TAPPI or ISO brightness (1,2). Papers are graded and sold based on brightness, which has led to an intense focus on this aspect of paper and a competitive drive amongst papermakers to improve it.
Higher Brightness Means Broader Gamut

What makes high-brightness paper better than low-brightness paper? In a word, gamut. Print gamut is defined as the volume enclosed in three-dimensional color space representing all the colors that can be reproduced using a specific paper and set of inks. A broader gamut provides more vivid colors. Low-brightness papers absorb a portion of the light that falls on them, reducing light available for illumination and preventing the inks from producing their full potential range of colors. Secondly, high brightness also gives unprinted areas a clean, white appearance.

Inherent Brightness vs. Fluorescent Brightness

To understand how a paper with a specified brightness will perform, it is important to understand how its brightness was achieved. High-brightness papers often use a fluorescent whitening agent (FWA) to achieve their brightness value. FWA works by absorbing ultraviolet (UV) energy, which is invisible to us, and re-emitting that energy as blue light, seemingly a neat trick. However, offset and gravure inks absorb nearly all of the UV energy that FWA needs to function (3). Consequently, FWA cannot contribute to expanding print gamut because the ink essentially deactivates the fluorescent whitener.

To verify the quenching effect of ink on FWA, two print gamuts were measured on a paper that has enough FWA to produce an extra six points of brightness. The only difference in the two gamuts is that one was measured with a calibrated amount of UV energy added to the illumination and the other was measured with no UV energy in the illumination. Removing UV energy from the source illumination has the same effect as removing FWA from the paper. Prints representing the eight Neugebauer colors—cyan, magenta, yellow, red, green, blue, black, and white—were produced to typical commercial optical density targets using a commercial offset ink set and laboratory proofing press. Figure 2 shows the two print gamuts superimposed on each other in three-dimensional color space. The semi-transparent green gamut was measured without UV. The gamut shown as a wire frame was measured with UV. As expected, an expansion of the gamut can be seen in the white region, where there is no ink to filter out UV energy, but all the other colors of both gamuts match up exactly. This confirms that FWA does not improve the paper’s range of color reproduction for solid colors. FWA may provide a broader gamut in the halftone areas, but this was not investigated since our proofing press can produce only the eight solid Neugebauer colors.

Inherent brightness is the brightness of the sheet without the fluorescent component. This is easily measured by placing the brightness meter’s UV filter in the source light’s path while making measurements. Inherent brightness is a better indicator of the print gamut a paper will deliver than either TAPPI or ISO brightness. Your paper representative should be able to tell you how much of your paper’s brightness comes from fluorescence, if any.
Effective Brightness Depends on Opacity

High-brightness paper can provide good illumination for the printed image only if it has adequate opacity. However, if opacity is inadequate, the effective brightness of each point on the print is controlled by whatever happens to be printed on the reverse side of the page at that location. Note how the cheek of the model in the cosmetics ad in Figure 3 has a gray pallor because of the drop in effective brightness there compared to the skin below her cheek. A paper's potential drop in effective brightness is determined by subtracting the brightness reading on a single sheet backed by a black body from the standard brightness reading taken on a thick stack of unprinted sheets.

How Opacity and Print Showthrough Affect Illumination

Opacity is a measure of paper's ability to prevent light from penetrating from one side of the sheet to the other. It can be thought of as the percentage of light that is blocked from being transmitted through the sheet. Opacity is expressed as the ratio of two reflectance readings. One is the reference reading, which is either taken on a single sheet backed by a white body with a reflectance of 89 percent or on a thick pad of sheets of paper from the same lot. The second reading is the reflectance of a single sheet with a black backing. Opacity is the ratio of the single sheet reading to the reference reading, expressed as a percentage. The closer together the single-sheet and reference readings, the closer opacity is to 100 percent (4, 5, 6).

Figure 4 shows the difference in hiding power between two papers with the same basis weight, but with different opacities.

A printed page with low opacity can result in a few forms of poor appearance.

1. Anything printed on the reverse side of the page or printed on the page below interferes with the image. See the model's neck in Figure 3.
2. As mentioned earlier, effective brightness is strongly influenced by opacity.
3. A white or highlight area with dark printing on the reverse side can result in a mottled appearance if the paper is not of uniform thickness and weight.

Ink Strike-In Influences Print Showthrough

Ink strike-in typically results in three to five extra points of print showthrough; therefore, anything that improves ink holdout will also improve the effective opacity of the sheet. The effect of ink strike-in on print showthrough is measured using a sheet printed with a solid color, preferably black, and an unprinted sheet of the same paper. A sandwich is made of the printed and unprinted sheets with the ink layer in the middle. A thick pad of the same paper or an 89 percent reflectance body backs the sandwich for two reflectance readings. The printed sheet is toward the light source for one reading and the unprinted sheet is toward the light source for the other. The difference between the two readings indicates the degree to which ink has penetrated into the thickness of the printed sheet, reducing the effective thickness available to provide hiding.

Small Opacity Improvement Results in Significant Reduction in Print Showthrough

TAPPI opacity for papers that are intended for two-sided printing starts in the low 80s. Most of them fall in the high 80s and low 90s. Just a few points increase in paper opacity can create a major improvement in the appearance of the print. The important factor in determining showthrough appearance is not how much light the paper blocks, but how much it transmits. For example, paper with 90 percent opacity allows 10 percent of the printed image from the opposite side to
show through. Paper with 95 percent opacity allows only 5 percent of the backside image to show through, a 50 percent improvement. The six-point opacity difference between the two papers in Figure 4 corresponds to a 46 percent reduction in transmitted light. The difference in showthrough performance is easily seen in the figure. By contrast, a six-point increase in paper brightness will increase the illuminating power of the sheet by only about 8 percent.

Relative Impact of Brightness vs. Opacity: Absolute Color vs. Color Difference

Print showthrough has more visual impact than paper brightness because humans' ability to judge absolute colors and our color memory are very poor, yet we have a remarkable ability to distinguish very small color differences.

Judging Absolute Color

The two red areas in Figure 5 look like quite different shades, but they are actually the same color. The colors surrounding the red areas create the perception that the reds are different. It is apparent from Figure 6, where the two red areas are connected to each other, that the two reds are actually the same color. The significance of our poor ability to judge absolute color is that it is difficult for us to notice differences in brightness between two papers unless they are viewed simultaneously, side by side. This is rarely the case in paper's end-use applications, but it is frequently the case when papers are compared for a purchasing selection.

Distinguishing Color Differences

The black and white stripes under the 93 percent sheet in Figure 4 are obvious to us even though there is only a 7 percent difference in reflectance between the two.

The significance of our excellent ability to detect color difference is that even modest print showthrough is highly noticeable and objectionable if the image on the opposite side of the sheet happens to interfere with the image being viewed. This is usually the case in end-use applications, but papers are typically selected based on their unprinted appearance.

Selecting Paper for Good Print Showthrough Performance

Papers are classified according to brightness so it is easy to know what brightness you are getting when you choose paper from a particular class, but what about print showthrough performance? Opacity is a very good predictor of print showthrough performance and you can find opacity information in a number of places. First, whether you buy through a paper merchant or direct from the mill, your paper sales representative should be able to give you opacity data for the papers they offer. Paper buying guides also include opacity information. OpacityWatch™ at http://www.titanium.dupont.com is a free, Web-based service that displays summary tables of opacity data sorted by paper classification and basis weight. An example is shown in Figure 7. These charts show the range of opacity available in the market and make it clear that you can often move to a lower-weight paper that provides the same or better opacity.

Benefits of Lighter Weight Papers

Substituting lighter weight paper saves money in two ways—less paper is needed to complete the job because each ton has more printing area, and if the finished piece is mailed, less weight means less postage. The environment benefits, too, since less energy, fewer trees, and less landfill space are used.
Summary

Paper brightness and opacity both influence print quality because they affect the amount and distribution of illumination available for the printed image. The market has emphasized brightness over opacity in the past for two main reasons:

1. When selecting paper for a print job, unprinted samples are typically viewed side by side. This practice is inconsistent with the paper's end-use because it overemphasizes small differences in brightness while ignoring the impacts of visual interference and reduction in effective brightness caused by print showthrough.

2. Papers are classified by brightness, which has led to brightness-based competition in the paper industry. Brightness increases have often been achieved with fluorescent whiteners. Yet fluorescent whiteners do not fulfill the primary reason for using high-brightness papers, which is more illumination for the printed image to produce more vibrant color (expand print gamut).

Opacity has more impact on print quality than brightness for several reasons:

1. Good opacity improves the effective brightness of the paper by blocking print showthrough.

2. A small improvement in opacity results in a large improvement in the uniformity of illumination, while a small improvement in brightness results in a small increase in illumination.

3. End-use brightness differences between papers are not very noticeable because they are almost always separated in time or distance and humans' ability to judge absolute colors and our color memory are very poor.

4. End-use print showthrough is caused by inadequate opacity and creates side-by-side color differences that are very noticeable to the human eye/brain.

References

1. TAPPI Test Method T 452 om-98 Brightness of pulp, paper, and paperboard (directional reflectance at 457 nm)


4. TAPPI Test Method T 425 om-01 Opacity of paper (15/d geometry, illuminant A/2°, 89% reflectance backing and paper backing)

5. TAPPI Test Method T 519 om-02 Diffuse opacity of paper (d/0 paper backing)


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