

HP Inkjet vs. Conventional Processing Photographic Print Quality

Consumer Preference Research Summary

Spencer & Associates Publishing, Ltd. and its *SpencerLab* Digital Color Laboratory conducted independent¹ focus group based research into consumer preferences regarding photographic print image quality. Significant effort was invested in establishing and executing an unbiased methodology in order to assure the quality and integrity of the research findings. The overall objective was to assess how far the image quality of inkjet prints has improved relative to the conventionally processed prints that are familiar to most consumers.

Consumers who take photographs were asked to rank photographic prints according to their individual preference for print image quality. Participants compared prints of five different digital photos printed through conventional processing (wet-process, silver halide photographic paper) and through a variety of inkjet print systems (inkjet printers and high quality photo papers).

This research involved 427 participants, at least 60 in each of seven cities on three continents – in the United States (New York, California), Europe (France, Germany, Italy, Spain), and Asia (Japan). These participants provided 2,133 valid, independent preference rankings – each involving 45 pair-wise comparisons between print systems, some 95,985 comparisons. The following trends² were identified...

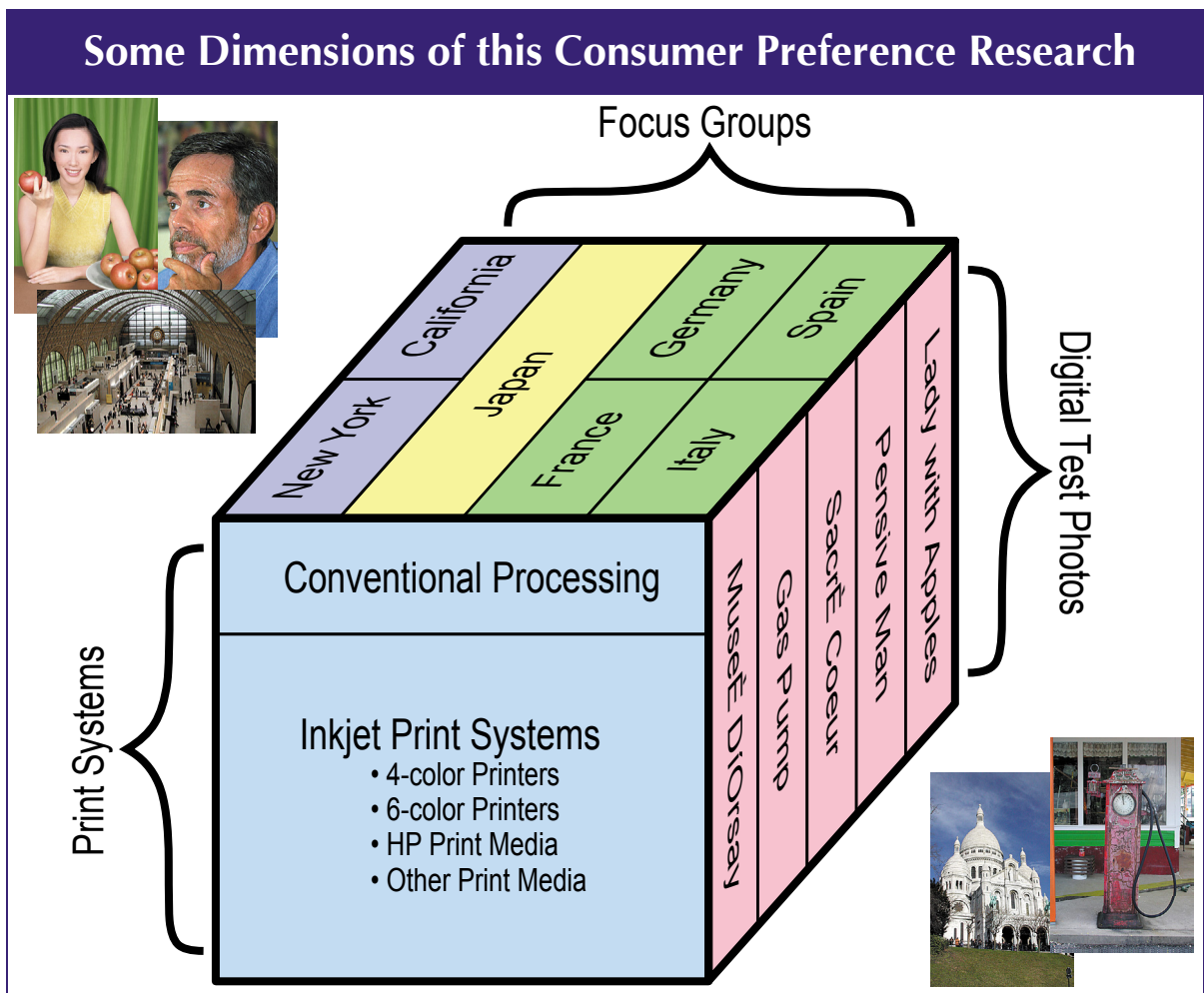
"I thought they were all developed!"

- ◆ **The print quality from current HP inkjet printers using *HP Premium Plus Photo Paper, Glossy* is on par with – or better than – conventional processing.** This result was found in all three regions (US, Europe, Asia). When print technology (including the use of high quality photo paper) was later divulged, many participants were astonished at the quality of these inkjet prints, **"We were all wrong and it is unbelievable how realistic and how authentic those photos can look. I find it amazing. You said inkjet printers? Well I think it is amazing, it really is amazing."**
- ◆ **Prints on *HP Premium Plus Photo Paper, Glossy* were preferred more often than those on Kodak's *Ultima Picture Paper-High Gloss* from the same HP printers in all three regions.** Prints on the HP photo paper from the *HP Photosmart 7550* were preferred nearly 2-to-1 over those on the Kodak photo paper from the same printer.
- ◆ **Prints from 6-color HP printers were preferred over those from 4-color printers in demanding situations.** Participants demonstrated a preference for 6-color over 4-color prints from the *HP Deskjet 5550*³, particularly for images with significant highlight areas.
- ◆ **After establishing their preferences among the various prints, participants were asked which factors – Richness, Realism, Sharpness, Smoothness – most influenced their print image quality preferences. Richness and Realism drove preferences higher for prints from HP printers with *HP Premium Plus Photo Paper, Glossy* than from conventional processing.**

The high-quality, color-corrected digital test photographs were selected to represent a realistic range of consumer experience: including people and scenery; memory colors such as skin tones, sky and grass; indoor and outdoor; highlight and shadow; and vivid and pastel color. After ranking the prints by image quality preference, participants – consumers of varied age and gender who take photographs – were asked to explain their preferences in terms of major quality attributes. Each participant then repeated this process for each of the five different images, and approximately 25% of the participants were randomly retained for qualitative discussions.

Quantitative data was analyzed to evaluate overall preference ranking, pair-wise preference, and attribute contributions. Analysis of the research results identified four consumer topics: preference for inkjet vs. conventionally processed prints; the importance of paper choice within an inkjet printing system; the importance of 6-color versus 4-color inkjet printing; and which image quality attributes are most influential.

"From an inkjet printer that we could have at home? I mean in an ordinary household of ordinary people? Well that is an amazing result, that is wonderful, I'm amazed."



(The full report may be downloaded at www.spencerlab.com.)

¹ Although this research was sponsored by the Hewlett-Packard Company, as an independent test laboratory with a broad base of industry clients, SpencerLab believes that this report maintains its reputation for the integrity of its test procedures and analyses.

² Statistical confidence is discussed in this report in **Research Methodology > Quantitative Analysis**.

³ The HP Photosmart 7550 uses this same 6-color technology and ink cartridges on HP Premium Plus Photo Paper, Glossy.

Research Findings

As noted above, the overall objective of this research was to assess how far the image quality of inkjet prints has improved relative to the conventionally processed prints that are familiar to most consumers. Unbiased consumer preference data, based solely upon print image quality, was acquired and analyzed.

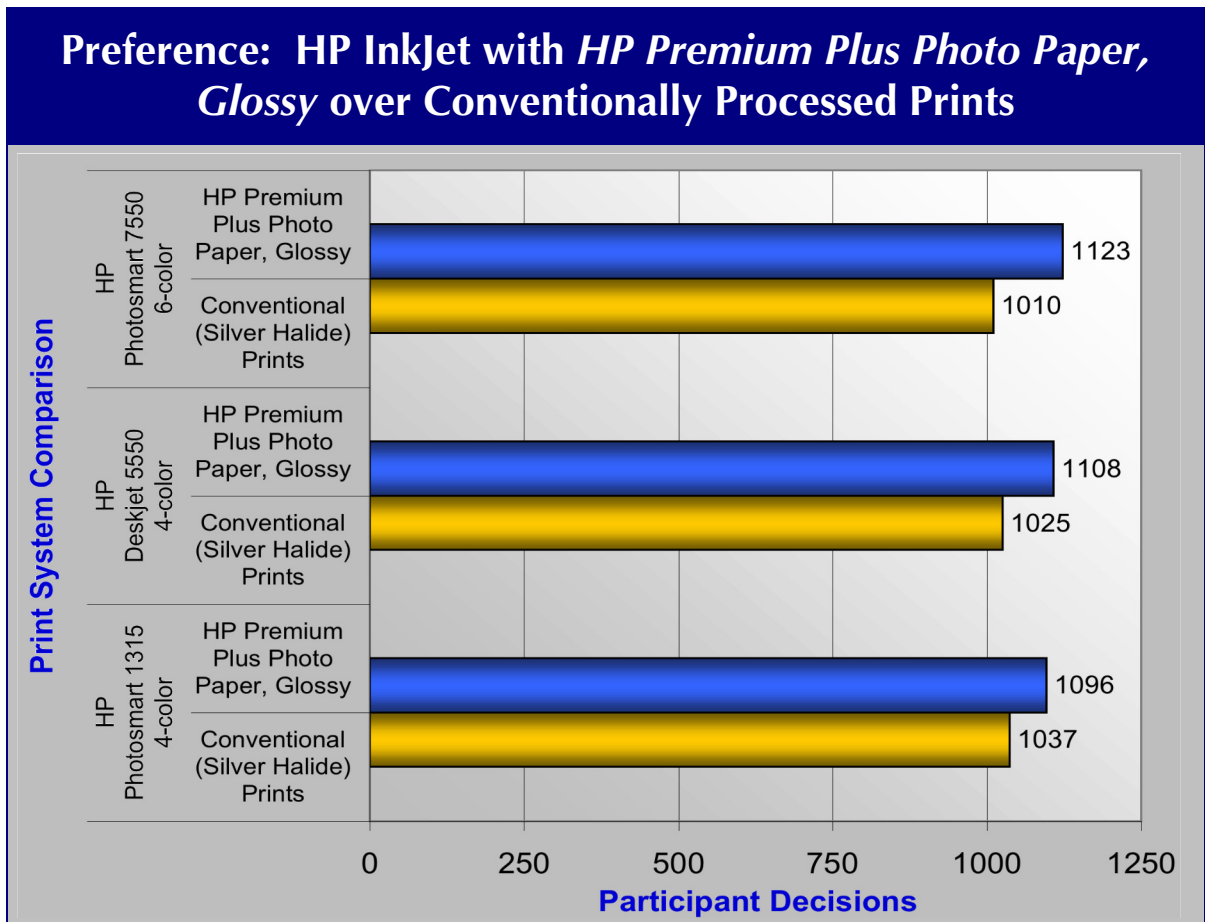
HP Inkjet vs. Conventionally Processed Prints

A primary aim of this research was to specifically assess how prints from HP Print Systems (HP inkjet printers using *HP Premium Plus Photo Paper, Glossy*) compared to conventional processing of the same images. Our research concluded that **on average, the print quality from current HP inkjet printers using *HP Premium Plus Photo Paper, Glossy* is on par with – or better than – conventional processing in all three regions: US, Europe, and Asia.**

"I didn't even think about developed or printed."

In specific pair-wise comparisons, prints from the 6-color *HP Photosmart 7550* inkjet printer on *HP Premium Plus Photo Paper, Glossy* were preferred 11% more often than conventional processing, 1123 to 1010 times. Prints from the 4-color *HP Deskjet 5550* on the HP photo paper were preferred over conventionally processed prints 8% more often. Prints from the *HP Photosmart 1315* on the HP photo paper were on par with conventional processing (5% preference).

These results are shown graphically below:

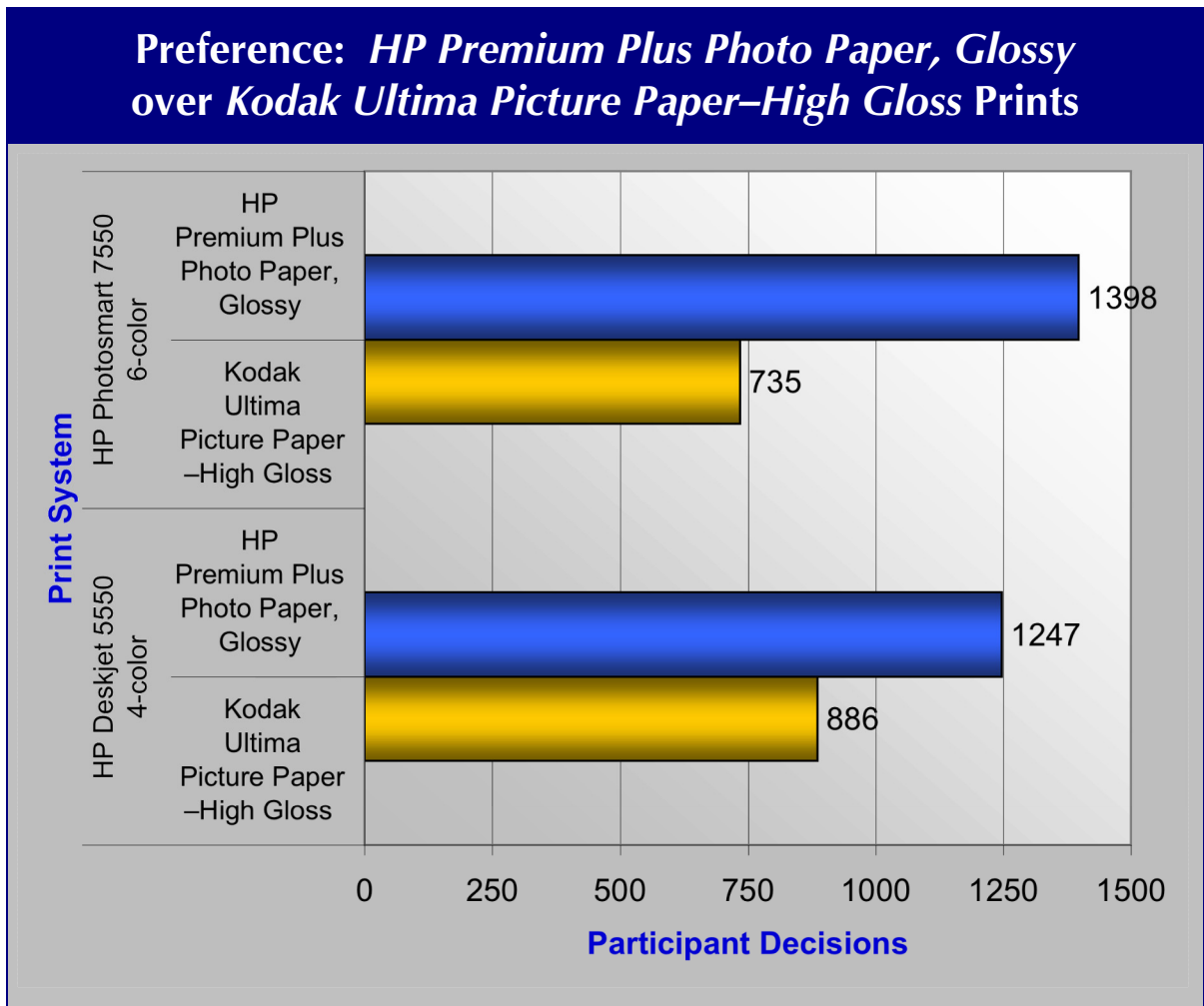


HP vs. Non-HP Photo Paper

A second objective of this research was to assess consumer image quality preference from HP printers for the HP photo paper over an alternate. The 6-color *Photosmart 7550* and the 4-color *Deskjet 5550* were each tested with both *HP Premium Plus Photo Paper, Glossy* and *Kodak Ultima Picture Paper–High Gloss*. Both products represent their vendor’s current best glossy inkjet photo paper, designed to look like professional photographs.

"I put this print [Photosmart 7550 on HP photo paper] first because that's my idea of an authentic, believable, real photo ... details that really matter."

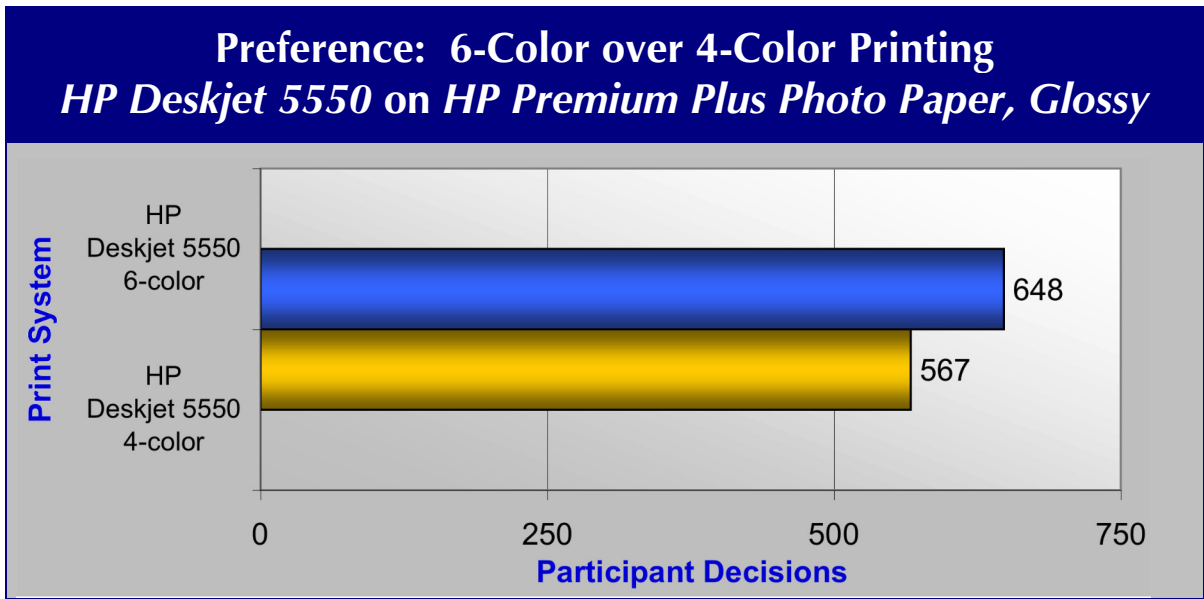
Pair-wise analysis of the head-to-head comparison data demonstrated that prints on *HP Premium Plus Photo Paper, Glossy* were preferred more often than those on *Kodak Ultima Picture Paper–High Gloss* from the same HP printers in all three regions. Prints from the 6-color *HP Photosmart 7550* on the HP photo paper were preferred to those on the Kodak photo paper 1398 to 735 (nearly 2-to-1), 90% more often; prints from the 4-color *HP Deskjet 5550* on the HP photo paper were preferred 1247 to 886, 41% more often than those on the Kodak photo paper. These results are shown graphically below:



The only time prints from HP printers were on average not ranked at least on par with those from conventional processing was when non-HP photo paper was used.

6-Color vs. 4-Color Printing

The *HP Deskjet 5550* printer can print in either 4-color or 6-color modes⁴ on *HP Premium Plus Photo Paper, Glossy*. Pair-wise data analysis of the European venue results⁵ showed that prints from this HP printer in 6-color mode were preferred 14% more often than prints from the same printer in 4-color mode, as shown graphically below:



For individual images with more highlight detail⁶, 6-color over 4-color preferences ranged from 25% to 41%. Note that the *HP Photosmart 7550* incorporates the same print technology as the *Deskjet 5550*.

Attributes Results & Discussion

After the participants established their preferences among the various prints for each photographic image, they were asked to consider four predefined image quality factors – Richness (vividness), Realism (true-to-life), Sharpness (detail), and Smoothness (lack of grain or other artifacts). Each was carefully explained, both verbally and with written definitions in the local language, and understanding was confirmed. Qualitative discussions affirmed that these four attributes most influenced participants' print image quality preference, more than gloss and other image print quality factors⁷. Participants were asked to add any other print quality attributes, and how much each of these attributes contributed to their preference judgments in a positive or negative way.

They determined that Richness and Sharpness were more positive factors, while Realism and Smoothness had a less positive effect – note that a lack of Realism would contribute negatively, as would a lack of Smoothness (graininess). Richness correlated most strongly with image quality preference, and Sharpness second – implying that when prints are adequately true-to-life (realistic) and not grainy (smooth), consumers prefer more vivid (rich) and detailed (sharp) prints.

⁴ In the *HP Deskjet 5550*, a tri-chamber color cartridge is used in both print modes; in lieu of the 4-color mode's black print cartridge, in 6-color mode a special tri-chamber color cartridge is used to allow 6 different colors to mix.

⁵ In European venues, an enhanced method of representative ink cartridge selection was used – described in *Research Methodology > Print Sample Preparation*.

⁶ *Lady with Apples* and *Gas Pump* are described in *Research Methodology > Test Images*.

⁷ When some participants were told in follow-on discussions that only one print sample of each photographic image was conventionally processed, they were generally able to identify those prints by their gloss uniformity; however, they stated that the pre-defined image quality attributes of Realism, Richness, Sharpness, and Smoothness were more important print quality factors.

There was, however, an interesting difference in the participant's response to conventional processing: Smoothness contributed more positively than Realism. This suggests that if not for its Smoothness, consumers might rate conventional processing lower by faulting its Realism. **Print quality preferences for HP printers with *HP Premium Plus Photo Paper, Glossy* over conventional processing were primarily driven by Richness and Realism.**

**"We take a photo because we are attracted to the moment;
we want to capture that moment.
That's why I want to find the same colors I enjoyed when I took the photo."**

Research Methodology

As noted above, significant effort was invested in establishing and executing an unbiased methodology in order to assure the quality and integrity of the research findings. The methodology included selecting and optimizing the test images; preparing the print samples; setting up the focus group participants and venues; collecting the print quality preference and attribute quantitative and qualitative data; and analyzing the results.

Test Images

The photographs were taken digitally or digitized on a high quality scanner in order to assure consistent original test images. The five photographic test subjects were selected to represent a realistic range of consumer experience, including: people and scenery; memory colors such as skin tones, sky and grass; indoor and outdoor; highlights and shadows; and vivid and pastel color. This is illustrated in the table on the following page.

These digital images were re-touched and color-corrected in sRGB⁸ at resolutions of at least 300DPI in 4x6" format. These optimized images were saved as JPEG files at quality levels as high as those typically obtained from 3-MegaPixel digital cameras.





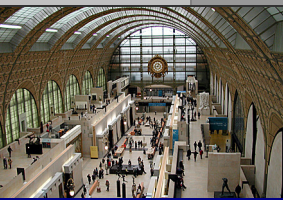
Print Sample Preparation

Copies of each image were printed on each of the print systems, which included conventional processing, and various inkjet printers with photo papers.

Conventional prints were selected by reviewing samples developed from numerous digital photo processors in order to find representative and consistent sources. Selection was limited to consumer retail facilities. After finding considerable variation among developers in the US, a large drug store chain with in-store Fujicolor Crystal Archive processing was selected as the most representative and consistent through an extensive review process. In Japan our need for 4x6" format size led us to Fujicolor Ever-Beauty professional photo lab development; however, unable to find consistency in our European efforts, it was decided to use additional US prints in Europe.

Inkjet prints for the US and Asian studies were made from a single printer and ink cartridge, selected at random and assumed to be representative of that manufacturer/model print system. Although printhead variations were modest in comparison with variations found in conventional processing, print sample preparation methodology refinements improved the representative selection process for European testing. Since print heads may be contained within an ink cartridge or may be integral to the printer (depending upon manufacturer/model), the most representative print system was selected from a group of five cartridges or printers, as appropriate, after a careful review process; if additional ink was required, the next-best system was used.

⁸ sRGB is a standardized RGB color space, often used in consumer photographic inkjet printing.

Test Images			
Image	Title	Comment	Image
	Lady with Apples	A studio scan of an Asian female chosen to highlight "Realism" and "Smoothness"	
	Pensive Man	Digital indoor photo of Caucasian male chosen to highlight "Realism" and "Sharpness"	
	Sacré Coeur	Digital outdoor photo of a building, sky, and grass chosen to highlight "Realism" and "Sharpness"	
	Gas Pump	Digital outdoor photo of a vivid object chosen to highlight "Richness" and "Sharpness"	
	Musée D'Orsay	Digital interior photo of a converted train station chosen to highlight "Sharpness"	

Minor print system model changes were made by region, maintaining the same total test size. In particular, the comparison of 6-color vs. 4-color printing was enhanced for the four European sites by including samples from an *HP Deskjet 5550* on *HP Premium Plus Picture Paper, Glossy* in both 6-color and 4-color modes using the same 4-color ink cartridge.

All prints were mounted in 8x10" dark neutral⁹ matting, with white back covering to minimize see-through, leaving all but 1/8" of the 4x6" image directly visible. Prints were marked with a random code to protect their identity. Participants always handled prints with white cotton gloves for protection, and the back covering did not allow participants to touch the print. Multiple print samples were made and protectively stored in light-shielded archival sleeves to minimize environmental degradation; duplicates were available as replacements if necessary.

Study Participants and Locations

Participants in this photo image quality research were consumers who develop film and/or own a digital camera. The overall sample pool consisted of 427 participants, 48% male and 52% female, ranging from 18 to over 65 years of age. Most considered themselves novice photographers, primarily taking pictures of people and scenery. There were at least 60 research participants in each of the seven cities, as detailed in the following table:

⁹ Chroma is within 1 ΔE of neutral.

Study Locations and Participants			
Region	City	Quantitative Participants	Qualitative Participants
Europe	Paris, France	63	15
	Berlin, Germany	60	15
	Milan, Italy	60	15
	Madrid, Spain	60	15
Asia	Tokyo, Japan	60	20
United States	Plainview, NY	60	25
	Irvine, CA	64	0
Totals	7	427	105

All print quality judgments were made under controlled conditions at specially designed black-and-white surfaced viewing stations with 3500-4000°K lighting. Facilitators were careful to only use terms such as “photos” or “images” (translated, as appropriate) rather than making any specific references to conventional developing or to digital printing technology.



Preference Ranking (Pair-Wise Comparisons)

Focus groups were structured into five-participant mini-groups and conducted in the local languages. Each study participant was asked to rank prints of a particular test image, one from each of the various print systems, according to his/her preference for image quality. Prints were arranged face down in random order. Participants were asked to compare the first pair of prints and determine their preference. Each following print was then compared in a pair-wise fashion with each of the prior ones, from which each participant’s preference among the group was determined, in rank order from best to worst.

Each participant repeated this quantitative process for each of the five test images.

Attribute Evaluation

After recording their rank order preference, each participant was asked to explain his/her judgments in terms of four or more color print quality factors or attributes, recording whether each quality factor positively or negatively contributed to the preference decision. Four attributes were

pre-defined: Richness, Realism, Sharpness, and Smoothness (lack of graininess). Additionally, participants were permitted to “write-in” other factors that contributed to their ranking, such as gloss, contrast, etc.

Qualitative Focus Group

One-quarter of the focus mini-groups were randomly selected for qualitative discussions to explore the reasons behind their preference rankings, and gather commentary about their thinking. Discussion included photo-taking habits, preconceptions of conventional processing vs. printed output, and opinions regarding the relative importance of image quality attributes. Responses were colorful and reflected the participants’ passion for pictures.

Quantitative Analysis

After data entry, verification, and consolidation, various computer analyses were performed. Preference rankings were analyzed in various areas of interest. Averages of all five test images were computed with equal weighting.

Overall preference rankings were at times fairly close, and a better understanding of the results was obtained by analyzing the detailed pair-wise comparisons.¹⁰ Since methodology recorded the preference for every instance where a participant compared the print quality and attributes of print system ‘X’ with print system ‘Y’ for each X-Y pair, overall a total of 95,985 pair-wise preference comparisons were available for analysis.

Confidence Levels

Statistical analysis of the pair-wise judgments included two approaches, consistent with methods used in various groups within our industry. One method assumes interdependence among the individual pair-wise comparisons, relating to the “law of comparative judgments”.¹¹ The other method assumes independence, reducing to the well known coin-toss analysis:¹² Assuming a single-tailed normal distribution of K preferences out of N decisions, with confidence calculated as the Normal Standard Distribution of $(K-Np) / \sqrt{Npq}$, and given the large number of participants and multiple decisions by each, many of these study results have a statistical confidence in excess of 95%. These include preference for the 6-color *HP Photosmart 7550* and 4-color *Deskjet 5550* inkjet prints on the HP photo paper over conventional processing; preference for the *HP Photosmart 7550* and 4-color *Deskjet 5550* inkjet prints on the HP photo paper over those printers’ prints on the tested Kodak photo paper; and preference for the 6-color inkjet prints over the 4-color inkjet prints from the *HP Deskjet 5550* on the HP photo paper.

Other

Our analysis found little overall variation by geography, especially when compared with preference variation from image to image. Although participants had a stated desire for realism, they often preferred prints that looked like what they wanted, not necessarily accurate representations of the original scene. Overall, the methodology was effective internationally, with the minor improvements implemented in Europe further increasing confidence.

**"I am very surprised, they're all so clear and sharp.
I'm amazed you can produce such quality with a printer."**

February 2003

¹⁰ Not all pairs were available in all venues.

¹¹ According to *Optical Radiation Measurements*, Bartleson, C. James and Grum, Franc editors, formally set down by Louis Leon Thurston in 1927.

¹² For example, *Concepts and Applications of Inferential Statistics*, Lowry, Richard, Professor of Psychology, Vassar College.

About *spencerLAB*

The *SpencerLab* Digital Color Laboratory is an independent printer evaluation facility that provides services to vendors and corporations for whom color printing is mission-critical. The Laboratory follows strict guidelines in the integrity of both methodology and reporting; vendor-sponsored studies do not guarantee favorable results. *SpencerLab* has developed industry-standard test software, and performs print quality, throughput speed, ink and toner cartridge yield and cost-per-print/TCO, and ease-of-use analyses for color and monochrome printers in all technology classes, from inkjet and laser printers to digital color presses.

SpencerLab is a division of Spencer & Associates Publishing, Ltd., a premier IT consulting boutique specializing in the application of Digital Color Technology to all aspects of color imaging. Spencer & Associates has been providing strategic support to manufacturers in product planning, development, and launch since 1989. Color printing workflow analysis, print system selection, and usage optimization services are provided to corporate users.

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