Perception of Sparkle in Anti-Glare Display Screens

Alicia Stillwell and James A. Ferwerda

Munsell Color Science Laboratory, Center for Imaging Science, Rochester Institute of Technology, Rochester, NY 14623

Howard Hovagimian, and Ellen M. Kosik Williams

Corning Incorporated, Corning NY 14831

Abstract: *We describe a series of psychophysical experiments to quantify the relationships between anti-glare glass treatments and perceived sparkle in emissive displays. The experiments show that: 1) a new measure pixel-power-deviation (PPD) correlates well with perceived sparkle; 2) tests of sparkle using small samples provide a conservative bound on perceived sparkle in display-sized samples; and 3) sparkle visibility is affected by the content of displayed images.*

1. Objective and Background

Modern electronic displays are typically composed of emissive elements (LCD/backlight, OLED, etc.) faced with a sheet of cover glass. The cover glass can be designed to have a range of transmissive and reflective properties, and one goal is to optimize displayed image quality (contrast, sharpness, etc.). An important quality factor is the effect of environmental light reflected off the display surface. Bright light sources and high contrast surrounds can produce veiling reflections that seriously reduce the quality and usability of displayed images. To address this problem, anti-glare (AG) treatments can be applied that typically provide a rough surface to reduce the contrast and visibility of surface reflections. While these treatments can be effective in reducing the impact of surface reflections, and may also improve surface feel and reduce fingerprint visibility, they can sometimes produce a transmission artifact known as "sparkle" where the displayed image appears to be covered by small colored highlights that scintillate with relative movement of the display and observer. The sparkle effect can be disturbing and can severely reduce perceived image/display quality. In this paper we describe a series of psychophysical experiments to quantify the relationships between anti-glare glass treatments and perceived sparkle in emissive displays.

Sample	PPDr Value
Reference 1	0.6
Reference 2	4.2
Reference 3	7.7
Reference 4	12.1
Test 1	0.7
Test 2	1.0
Test 3	2.5
Test 4	3.1
Test 5	4.0
Test 6	5.2
Test 7	5.2
Test 8	6.4
Test 9	7.1
Test 10	8.8

Figure 1: PPDr values of reference and test samples.

2. Results

A wide variety of emissive displays are available with different pixel geometries and pitches. These factors are known to affect the sparkle phenomenon, with sparkle generally being more problematic as pixel pitch increases [1]. To provide data relevant to modern mobile displays, we used an 9.7 inch LCD tablet with a high-resolution display as our emissive source. The display has square pixels with a pitch of 264 pixels/inch (95.2 μm/pixel).

We used a test set of anti-glare glass samples with surfaces roughened to different degrees by etching treatments. We measured the light scattering properties of the samples using the pixel-power-deviation (PPDr) technique developed by Gollier, *et al*. [4]. In this technique, samples are placed against an LCD panel displaying a uniform green image (only green sub-pixels illuminated), and a high-resolution camera measures the transmitted distributions of light produced by each sub-pixel. The standard deviations of the distributions for different glass samples are normalized with respect to the distribution measured directly off the display to compute their PPDr measures. The PPDr values of the set of anti-glare glass samples used in the experiments are given in Figure 1.

We conducted three psychophysical scaling experiments to understand the relationships between the properties of anti-glare display glass and perceived sparkle. All the experiments used the same graphical rating procedure [2].

The experimental setup is shown in Figure 2. The glass samples

Figure 2: Setup used in the sparkle scaling experiments. Reference samples scale is along the bottom. Test sample in this case showing a text image is on the top.

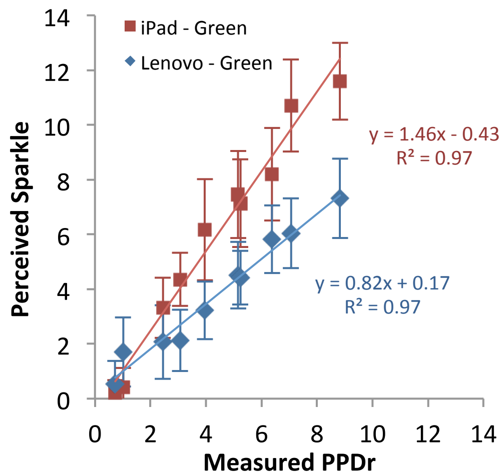

Figure 3: Results of experiment 1 - Note the linear relationships between measured PPDr and perceived sparkle.

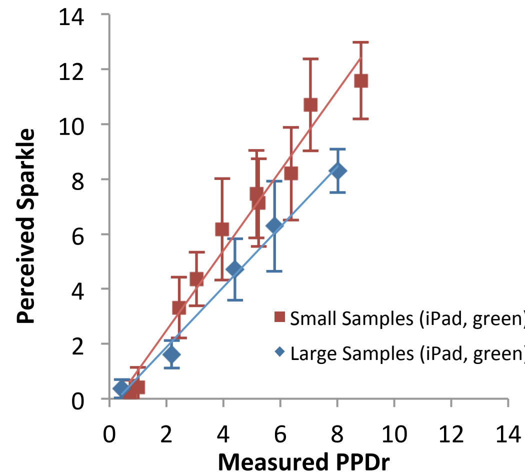

Figure 4: Results of Experiment 2 - Note that sparkle measured using small samples is a conservative predictor of sparkle on display-sized samples.

were glued to the backs of 35mm slide mounts, which provided a standard viewing aperture (35mm x 22mm), and allowed for easy handling of the samples without smudging. The samples were placed directly against the touchscreen of the tablet with the AG surface closest to the viewer. Four "reference" samples with PPDr values 0.6, 4.2, 7.7 and 12.1, were placed in a row along the bottom of the display from low to high (left to right). The "test" sample being evaluated was placed above the standard row.

On each trial of an experiment, observers were given a sheet of paper with a six inch line printed on it. Cross-marks made at four intervals across the line were used to represent the magnitudes of the reference samples. For each test sample, observers were asked to make a mark on the line to indicate how the sparkle of the test sample compared with the sparkle of the reference samples.

To calculate the observer's rating (s), the distance (d) from the left edge of the line to the mark was divided by the total line length (6 inches), then this value was multiplied by the sum of the lowest and highest reference PPDr values (s= d/6*(0.6+12.1). These ratings were then averaged across the 30 observers tested, to calculate a perceived sparkle value for each test sample. Observers viewed the samples from approximately 18 inches under normal office lighting conditions, however care was taken to avoid front surface reflections from the glass samples.

In Experiment 1 we wanted to understand how perceived sparkle relates to measured PPDr. The results are shown in Figure 3. The clear linear relationship shows that PPDr is a good predictor of perceived sparkle under the conditions tested. In pilot experiments we also measured the relationship between PPDr and perceived sparkle using a laptop LCD display (139 pixels/inch, 180 µm pitch). The results, also plotted in Figure 3 also show a strong linear relationship between the measures while also supporting the assertion made by Becker and Neumeier [1] that sparkle is more problematic in higher-resolution displays.

In Experiment 2 we wanted to understand if perceived sparkle measured using small samples would be a good predictor of perceived sparkle in mobile display-sized (phone, tablet) samples. The methods and procedures used were the same as those of Experiment 1, but the test samples now measured 3.5 by 5 inches. The results are shown in Figure 4. Data for the small samples is also plotted for comparison. The results show that for a given PPDr value, perceived sparkle is slightly lower for the large samples than for the small samples, but not significantly so until the high PPDr range. This result suggests that sparkle testing with small samples would be a conservative predictor of perceived sparkle in mobile display-sized glass units.

Finally in Experiment 3 we investigated the effects of image content on perceived sparkle. The images used are shown in Figure 5 and included both text and photographic images to represent the kinds of content that consumers might typically view on a mobile device. All images were rendered at the native resolution of the tablet. The experimental methods, procedures, and observers were the same as the ones used in the previous experiments.

The results of Experiment 3 are shown in Figure 6. As in Experiment 1, linear trends were seen between measured PPDr and perceived sparkle, however the data also shows that image content can have a significant impact on perceived sparkle. First note, that the sparkle ratings for the green screen are the highest at each PPD level (except PPD = 8.8, and here is within the error bounds of the contender). Second, observe that the sparkle ratings for the photographic images (Portrait, Busy, Landscape) are significantly lower than the green screen across much of the PPD range and that they also differ from each other, with the "Busy" image leading to low sparkle ratings likely due to visual masking effects [3], while the "Landscape" image with its large uniform areas lead to ratings similar to the others at low PPD levels but then acts more like the green screen at higher PPDs. The sparkle ratings obtained using the "Portrait" image fall between these two extremes, as does the "Text" image. These results suggest that while evaluating anti-glare products with green screens will be a conservative predictor of perceived sparkle in normal use, in most typical use cases it may lead to overly stringent requirements that may negatively impact other aspects of product production and performance

Figure 5: Images used in Experiment 3. Counterclockwise from top left: Green, Text, Landscape, Busy, Portrait.

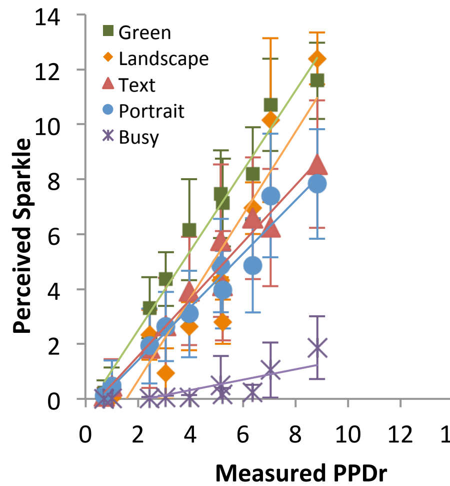

Figure 6: Results of Experiment 3 – Note that with the exception of the "Landscape" image at high PPDr values, samples tested with real images show lower sparkle than those tested with a green screen.

3. Impact and Summary

In this paper we have described a series of psychophysical experiments that quantify the relationships between anti-glare glass treatments and perceived sparkle in emissive displays. The experiments show: 1) that a new measure pixel-power-deviation (PPDr) correlates well with perceived sparkle; 2) that tests of sparkle using small samples provide a conservative bound on perceived sparkle in display-sized samples; and 3) that sparkle visibility is affected by the content of displayed images. While these results are promising and useful there is still much work to be done. First, the glare-reducing properties of glass samples should be evaluated and compared with sparkle measures to understand tradeoffs in these factors. Second, the effects of image content should be studied more systematically to allow sparkle to be predicted under typical use conditions. Finally, the effects of motion on perceived sparkle (whether from dynamic content or from observer/device movement) should be studied. Together these efforts should allow the development of psychophysical models of the effects of anti-glare glass treatments that should enable the production of emissive display systems that provide high image quality under widely-varying viewing conditions.

4. References

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