# 75.3: Is Brighter Always Better? The Effects of Display and Ambient Luminance on Preferences for Digital Signage

**Pearl S. Guterman, Kazuho Fukuda[2], Laurie M. Wilcox, and Robert S. Allison**
**Centre for Vision Research, Dept. of Psychology, York University, Toronto, Ontario, CANADA**
**[2] Dept. of Information Processing, Tokyo Institute of Technology, Yokohama, Kanagawa, JAPAN**

## Abstract
*Preferred brightness may depend on many variables including image luminance and ambient illumination. To better understand the effects of these variables we asked observers to rate natural images according to their preferred brightness. Surprisingly, ratings plateaued at moderate luminance levels, and were only weakly influenced by ambient lighting.*

## 1. Introduction
Digital signage is quickly replacing traditional sign formats in the marketplace. Its ability to support dynamic multimedia and low cost of installation has driven deployment in shopping malls, fast food chains, airports, and most recently common areas in universities. For example, this form of signage has been adopted in London's Underground transit system, where large video boards line the walls of the subway platforms and digital signs by escalators display bright, eye-catching advertisements. However, little is known about the effects of luminance and ambient lighting on viewer preference or enjoyment; this can impact the time spent viewing the display and therefore the effectiveness of the displayed content. Optimizing display settings and ambient lighting according to viewer preferences also has the added potential for energy and cost saving benefits [1].

To improve viewer satisfaction and maximize the potential impact of signage, it is important to consider the properties of human brightness perception. First, it is well recognized that perceived brightness for simple stimuli (black/white disks) follows a power function with a slope of around 0.33 [2]. The consequence of this non-linear relationship is that equal increases in display luminance do not necessarily produce equal corresponding increases in perceived intensity. When complex images of natural scenes are used, there is a similar relationship between perceived brightness and luminance but with a different power-law exponent and an additional exponential-decay term [3]. Given this, it is likely that viewer preference for image luminance will also exhibit a non-linear relationship.

Another perceptual factor that may influence brightness preference is contrast sensitivity, that is, the ability to discriminate between luminances. Studies [4, 5, 6] have shown that ambient illumination, which reflects off the viewed surface, can reduce the perceived contrast of displayed imagery [5]. Further, at high luminances, the percept of flicker is increased creating corresponding reductions in image contrast and resolution [7]. Therefore, understanding the relationship between the percept of the viewer and physical characteristics of the display and viewing environment is critical to providing a better viewing experience.

It has been long known that ambient lighting influences the perception of images. In a brightness adaption study [8], ambient illumination significantly altered observers' contrast discrimination thresholds. The results of such studies can be used to calibrate display settings with respect to ambient lighting levels to improve image quality and viewing experience, and to minimize visual fatigue [9].

Studies have been helpful in characterizing the relationship between sign and background luminance on viewer satisfaction. A recent series of experiments [10] assessed preferred brightness for outdoor signage using a scale model of outdoor storefronts with traditional acrylic text-based signs (back lit using red light-emitting diodes) at a range of sign and ambient luminances. The results showed that, for text content, viewers prefer brighter signs in brightly lit environments. Furthermore, when adjacent signs were present, viewers preferred slightly higher sign luminance. Hence, this study provides a useful point of reference from which to examine the effects of display and ambient luminance on indoor signage.

It is important to note that image complexity has also been found to influence the perception of brightness [3], and is another critical factor in designing a comfortable viewing experience. Unlike achromatic patterns such as sinusoidal gratings—the mainstay of visual psychophysics—the perceived brightness or contrast of complex images of natural scenes is not well described by a simple power function [3, 11]. Rather, various elements such as the local luminance of regions within the image, and with respect to the surrounding environment, can influence perceived brightness. Using photographs of natural images under various display and ambient luminances would help to characterize and better predict viewer preferences for content that is typically displayed in commercial settings such as photographs or photo-realistic advertisements.

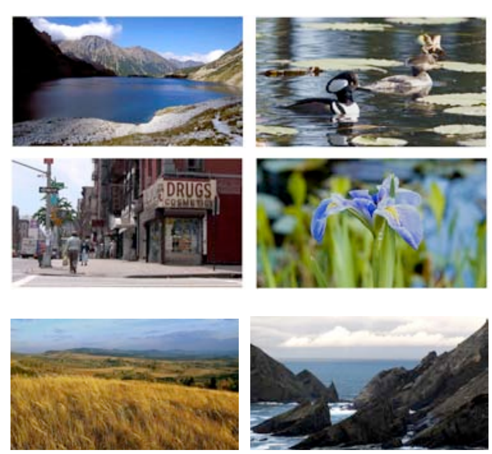


**Figure 1: Images of natural scenes used as stimuli.**


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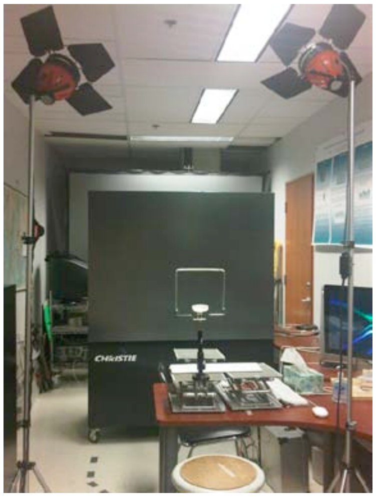

**Figure 2. Experimental set-up showing the back-projection display, chin rest, and film lamps.**

The goal of this study was to assess viewer brightness preferences for complex natural images displayed under a range of ambient luminances. Judgments of the brightness of the images at a range of luminances were also made to show how perceived brightness scaled with luminance for these stimuli and test settings. To facilitate generalization of our results to public and commercial settings, the ambient luminances tested here were consistent with measured lighting levels in shopping malls.

## 2. Method

Two laboratory experiments were conducted to evaluate viewer comfort as a function of image luminance and ambient lighting. In Experiment 1, a magnitude estimation technique was used to rate perceived brightness, and a rating scale was used to assess the brightness preferences for these same images. The tasks were performed under two ambient lighting levels to ensure that the magnitude estimates were not influenced by prevailing lighting. In Experiment 2, we also evaluated two higher ambient luminances consistent with sky-lit areas such as a mall atrium.

### 2.1. Participants

A total of 26 students at York University participated studying these experiments. The first experiment involved 8 graduate students, and the second 18 undergraduate students. The latter received credit as part of an introductory Psychology course based on their participation. All participants reported normal or corrected-to-normal vision. Written consent was obtained in accordance with a protocol approved by the University's research ethics board.

### 2.2. Materials

Stimuli were back projected onto an 80" screen using a DLV1920-DX projector (both supplied by Christie Digital Corporation) with an effective gamma setting of 1.8 determined by the computer graphics card. Brightness and contrast levels were set to 50%. The projector-to-screen distance was 175 cm, and the maximum image size was 125 x 74 cm (1920 x 1080 pixels). The screen-to-observer distance was 175 cm and the horizontal viewing angle was 40.37°.

Ambient luminances of up to 200 cd/m$^2$ (654 lx) were achieved with ceiling fluorescent lights with parabolic fixtures and two 650W film lamps directed towards the ceiling for indirect lighting (See Figure 1); this arrangement eliminated hotspots on the screen. During testing, the experimental computer monitor was covered with a black cloth to prevent interference with the test display. Prior to testing luminance levels were measured using a Minolta LS-110 photometer placed 1 m from the screen and pointed at a white paper in the center of the screen. The reflectance ratio of the paper was 0.96 bright according to TAPPI standards. Experiment 1 was completed under ambient luminances of 15 cd/m$^2$ and 60 cd/m$^2$. When converted to lux these corresponded to 49 and 196 lx [12]. In Experiment 1 we assessed ambient luminance levels of 15 and 60 cd/m$^2$, while Experiment 2 also tested ambient luminances of 15, 60, 100, and 200 cd/m$^2$; the corresponding lux values were 49, 196, 327, and 654 lx.

A Macintosh G5 computer running Matlab 8.1b and Psychophysics Toolbox Version 3 was used to control and display the test images and record observer responses. Stimuli consisted of 10 images of natural scenes that were adjusted using contrast normalization and set to a mean grey-scale value of 100 and a range of 0-255. To manipulate the display luminance the image grey levels were uniformly scaled. The natural scenes included images of natural and urban landscapes containing images of flowers, animals, and/or people (see Figure 1). Observers viewed the images from a distance of 175 cm seated in an adjustable chair to accommodate variability in observer height, and a chin rest supported the head (see Figure 2).

### 2.3. Study Design

Each of the 10 images was viewed at each of the 7 mean display luminance levels (10, 38, 78, 129, 192, 272, and 357 cd/m$^2$) under two (Experiment 1) or three (Experiment 2) ambient light levels. The ambient lighting conditions were tested separately in randomized blocks and participants were randomly assigned to blocks. In Experiment 1, the conditions were repeated twice for a total of 140 trials (i.e., 10 x 7 x 2) per ambient level. In experiment 2, the conditions were repeated three times for a total of 210 trials per ambient level.

### 2.4. Procedure

#### *2.4.1. Magnitude Estimation (Experiment 1)*

On each trial of the magnitude estimation task, observers were shown a reference image at 50% luminance at 102 cd/m$^2$ for 2 seconds and asked to give it a rating of 10. A blank screen followed this for 0.5 seconds, and then presentation of the same image at one of 7 luminance levels for 2 seconds. Observers were asked to rate the perceived brightness of the test image relative to the reference image. For instance, if the image looked twice as bright they would rate it 20, or half as bright 5. They could view the image pair again by pressing the "space" bar on the keyboard.

#### *2.4.2. Preference Rating (Experiments 1 and 2)*

Observers were shown an image at one of 7 luminance levels for 2 seconds. They then rated their comfort level on an integer scale from -3 to +3 (i.e., -3 = do not like, 0 = neutral, +3 = really like). To emphasize comfort with the image settings rather than content,

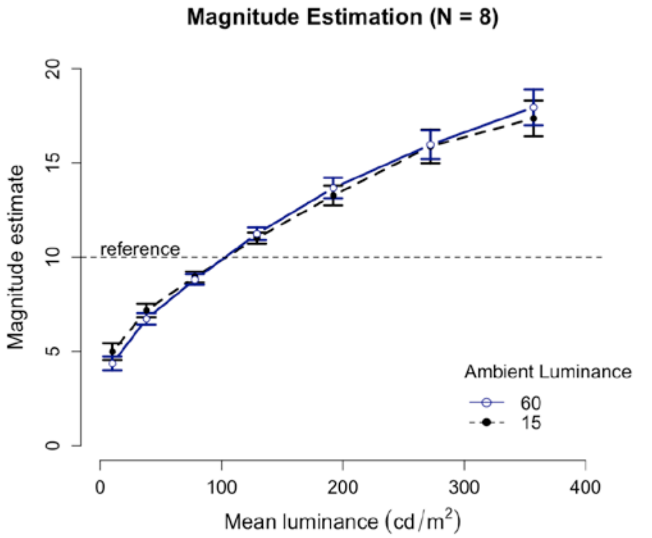


**Figure 3. Magnitude estimates as a function of mean display and ambient luminance. The error bars show 95% confidence intervals.**

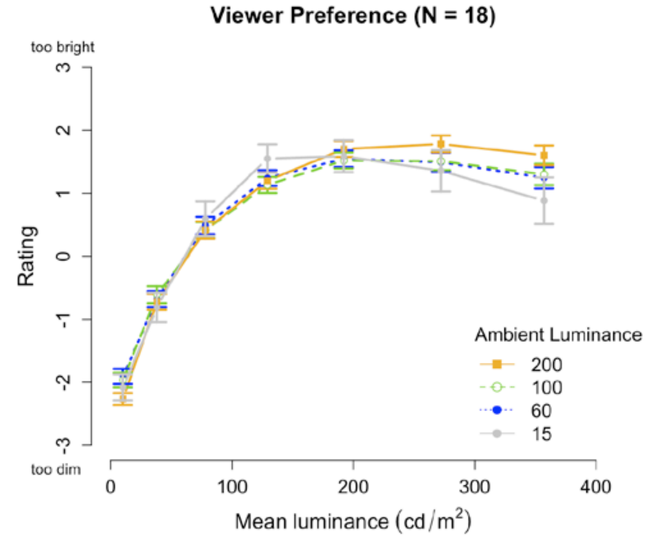


**Figure 4. Viewers' preferences with test images as a function of mean display and ambient luminance. Ratings for 15 cd/m$^2$ were from Experiment 1 with N = 8. The error bars show 95% confidence intervals.**

observers were told to ask themselves "How much do I like this image at this setting?" Observers recorded their ratings using a keyboard (in Experiment 1) or a horizontal slider bar on the screen using a computer mouse (Experiment 2). They could view the image again by pressing the "space" bar.

## 3. Results

Figure 3 shows observers' magnitude estimates of relative image brightness under varying ambient luminances. Ambient lighting did not significantly influence observers' estimates of relative brightness across a range of display luminances ($p > 0.05$; Wilcoxon signed rank), even though ambient luminances differed by a factor of 4. Thus, their perception of relative brightness was similar under the two ambient conditions. It should also be noted that the relationship between the magnitude of the display luminance and perceived brightness was well-fit by Stevens' power function model [3] with an exponent of 0.41 ± 0.0183. Observers continue to perceive increases in brightness as luminance is increased. However, the perceived increase in brightness resulting from a given increment becomes smaller. Further, the overlap of the data assessed at the two ambient levels shows that there is no effect of ambient illumination on the observers' relative brightness magnitude judgments.

Figure 4 shows the combined preference ratings from Experiments 1 (15 cd/m$^2$) and 2 (60, 100, and 200 cd/m$^2$). A multiple regression analysis was performed to determine if viewers' image setting preferences were a function of the display and ambient luminance. The results revealed a significant interaction between the display and ambient luminance ($B = 0$ .0001, $p < 0.001$). Probing the interaction further revealed a significant difference in preference ratings between the lowest and highest ambient levels (i.e., 15 and 200 cd/m$^2$) at extreme display mean luminances, as indicated by significant post-hoc Wilcoxon rank sum tests, ($p < 0.001$ and $p < 0.001$ for luminance levels of 272 and 357 cd/m$^2$, respectively). That is, there is a small effect of these ambient levels on preference ratings, but only between the highest and lowest ambient conditions at the highest display luminances tested. Although this was a between experiments comparison, we obtained virtually identical data from a control experiment in which we tested both 15 and 200 cd/m$^2$ ambient illumination conditions.

## 4. Discussion

Our data confirm that, regardless of ambient illumination, the perceived brightness of our complex images is not linearly related to luminance. Instead, as predicted by Stevens' power law, there is a law of diminishing returns where at larger luminances, the perceived increase in brightness resulting from a given increment becomes smaller.

As expected, preference ratings of these same natural images did not improve linearly as a function of luminance. Rather, the form of the response curve suggests a saturation or "inverted u" function, with a plateau evident near 130 cd/m$^2$ across the full range of ambient lighting conditions. At the lowest ambient lighting level there appears to be a peak in image brightness preference, which occurs between 100 and 200 cd/m$^2$ that suggests that viewers may have a brightness "sweet spot" under dim lighting. Most significantly, for all test conditions increasing the luminance beyond 130 cd/m$^2$ provided no benefits in terms of viewer preference.

Interestingly, these results echo data showing that readability ratings of storefront signs tend to plateau near 130 cd/m$^2$ [9]. This correspondence between such different data sets may be coincidental, but could reflect the existence of a preferred luminance for signage that can be applied across location and content. Further testing is needed to confirm this hypothesis.

It is worth noting that in our work, and that of [10] testing proceeded in blocks, and images were evaluated by our observers in a series. This may not be directly comparable to natural conditions, where signage is often encountered either in isolation or with neighbouring signage that is simultaneously visible. Additional testing will be required to determine if our pattern of results (e.g. the plateau at 130cd/$m^2$) will hold under different viewing protocols.

Ambient lighting had minimal impact on our viewers' brightness preferences. We found a tendency for observers to rate high luminance images lower when they were viewed under dim ambient lighting (15 cd/$m^2$) than any of the higher ambient conditions. This is in keeping with the common experience that a high-luminance display in a dark room can be perceived as dazzlingly bright, and this discomfort can lead to visual fatigue. However, over a large range of image luminance and ambient lighting combinations there was no effect of the ambient light level. This lack of an effect challenges earlier findings of an influence of ambient luminance on brightness preferences [10].

A potential explanation for the apparent discrepancy is that, under many conditions, as the ambient illumination increases so too does the amount of reflected and veiling light. This light scatter can cause reduced image contrast, particularly in displays with limited gain [9, 13]. We found that the luminance value where preference ratings plateaued was not significantly affected by ambient illumination. Seetzen et al have found that luminance corresponding to preferred brightness shifts with contrast ratio of the display [13]. We used a high-quality rear-projection Christie Digital™ display which preserved image contrast across the range of ambient lighting conditions. It is likely that at higher light levels, closer to those observed in bright daylight, we would eventually find a reduction in brightness preferences for our images. Since we were primarily concerned with moderate lighting, typical of that found in indoor environments, we did not try to assess these extreme levels.

Our use of full-colour natural scenes is an important aspect of this work, for it makes the results relevant to digital signage. The results show that viewer satisfaction can be achieved at moderate luminance levels, and that with high-quality display systems the effects of ambient lighting can be negligible. In this study all imagery was static, and it remains to be determined if these results can be applied directly to dynamic content.

## 5. Impact

Our results show that the mantra "the brighter the better" is not always true. There appears to be a point at which increasing image luminance has no benefit for, and may produce a decrement in, viewer satisfaction. Preferred luminance levels for images of natural scenes were found to vary only weakly (if at all) with ambient luminances over the range tested. The implications of our work are that 1) it may be possible to reduce current digital display luminance targets thus decreasing energy consumption and increasing display lifetime, without compromising viewer response, and 2) by considering the optimal range of image luminances identified here it will be possible to maximize viewer satisfaction and therefore potentially increase their attention to these displays. The next logical steps will be to determine whether these conclusions generalize to the large variety of content typically used in digital signage including text, dynamic imagery, and mixed-content displays.

## 6. Acknowledgements

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