Effect of Ambient Lighting and Monitor Calibration on Softcopy Image Interpretability

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Abstract

It is generally recognized that critical softcopy viewing of aerial imagery should be performed under darkened ambient light conditions (1-2 fc at the face of the monitor). Ambient light degrades interpretability by reducing image contrast.

With the move to a total softcopy environment for both image viewing and general office functions, there is a desire to operate in a typical office lighting environment. In a typical office with overhead fluorescent luminaries, it is common to find light levels of 15-20 fc or greater at the face of a monitor.

CRT designers have attempted to counteract the effects of ambient light by reducing screen reflectance and internal dispersion (halation). Such measures are of limited effectiveness. Increasing the luminance output of a monitor has greater potential impact as it can move the luminance range of the monitor above the ambient light contribution.

To investigate the effects of ambient light, imagery was displayed on monitors at two ambient light levels (dark and bright). Maximum and minimum luminance of the monitors was varied as was dynamic range (ratio of maximum to minimum luminance). Trained imagery analysts provided National Imagery Interpretability Rating Scale (NIIRS) ratings as well as resolution/contrast ratings using the Briggs target. Results were analyzed to determine the effects of ambient light and monitor calibration.

Introduction

Ambient illumination reduces the contrast of imagery viewed on softcopy monitors. Ambient illumination adds to the monitor output luminance by a constant amount and thus reduces contrast, particularly at low luminance levels. Consequently, viewing should be performed in a darkened ambient environment (1-2 fc).

In many cases, the viewing environment is not optimized and monitors are used in conditions of high ambient illumination. Unless monitor output luminance is increased, contrast discrimination will suffer.

The objective of the current study was to define the impact of high ambient illumination on image interpretability as well as to explore the impact of alternative monitor calibrations on decreasing the negative impact of high ambient illumination. A secondary objective was to explore the effects of varying the minimum luminance (Lmin) of the monitor as a means of increasing dynamic range.

Two monochrome monitors were used in the study. The monitors were operated under low and high illumination levels (2 and 20 fc) with varying calibrations. Imagery analysts were asked to perform Briggs target ratings[1] and to provide absolute and delta-NIIRS ratings[2] on a small sample of radar and visible imagery. They also provided NIIRS ratings on hardcopy versions of the same scenes they viewed in softcopy. Results were analyzed to determine the effects of ambient light, monitor type, Lmin, and dynamic range.

Background

The effects of ambient light on softcopy image display are well known in theory, but users are often unaware of the impact. It is not uncommon to find monitors positioned under bright office lights or even next to windows.

The effect of adding ambient light to a monitor is illustrated in Figure 1. The figure shows the effect of adding a constant 0.8 fL to a monitor with a calibration of 0.15 to 35 fL. Both curves show contrast modulation (Cm) as a function of input digital count or command level. The Cm values represent the contrast between adjacent counts. The upper curve shows substantially higher modulation at lower count values; these are the data under low ambient light conditions (~2 fc). The lower curve shows the effects of adding ambient light (~20 fc), contrast values are substantially reduced. The effect of this decrease is to reduce the number of discriminable contrast levels at, in this case, count levels below 150. As the contribution of ambient light increases, the loss in contrast increases.

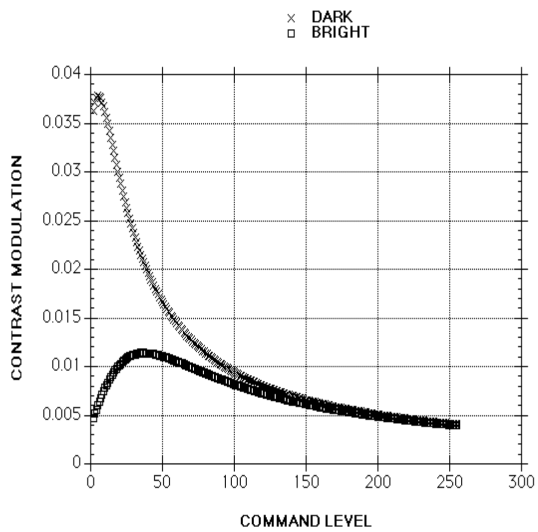

Figure 1. Effect of adding 0.8fL ambient light .

An earlier study[3] compared Lmin values of 0.015 and 0.15 fL, Lmax was set at 35 fL. A monochrome monitor was used with ambient light at ~ 2fc. Briggs and delta-NIIRS ratings did not differ significantly between the two Lmin values. In a second study (Leachtenauer and Salvaggio, 1996), two color monitors were calibrated to dynamic ranges of 0.2 and 3.3 fL to 23 fL and viewed in a bright ambient light condition (~18fc). The higher Lmin calibration showed a loss of 5 Briggs units (C-7) and a loss of 0.08 NIIRS. The higher Lmin calibration also had a significantly lower dynamic range.

Based on these previous studies, it appears that Lmin is relatively unimportant under conditions of low ambient light. In dealing with higher levels of ambient illumination, it would appear that the solution is to increase Lmin to some point higher than the sum of the monitor output and reflected ambient light. For the example shown in Figure 1, this would require an Lmin of ~1 fL. At the same time, however, dynamic range must be maintained. This would theoretically require, for the example given, an Lmax of 350 fL. Such values are generally not available with CRTs and may in addition have other negative effects on performance. A balance must therefore be achieved between increasing Lmin and maintaining dynamic range.

Method

Two monochrome softcopy monitor were evaluated in the current study. One of the monochrome monitors was established as the standard and was calibrated using a dynamic range of 0.1-35 fL (25.4 dB). Absolute NIIRS ratings were made on 10 radar and 10 visible images on this monitor in both low and high ambient light conditions. The other monitor was then compared to the standard using delta-NIIRS ratings. Absolute hardcopy ratings of the same imagery was also available for comparison. Finally, Briggs ratings (C-7 and C-3 target) were made on all of the monitor set-ups. Results were analyzed to determine the effects of alternative calibrations.

Monitors

Characteristics of the two monitors are summarized in Table 1. Monitor M-1 was used as the standard. Monitor M-2 was used for the comparisons performed. The Lmax and Cm values shown in Table 1 were reported by NIDL.[4] Both monitors have addressabilities of 1200 by 1600 pixels.

The monitors were driven using a 10 DAC, although data are fed through an 8 bit frame buffer before display. The driver board also employs a calibration tool which applies a perceptual linearization calibration to the data. The calibration applied is that developed by Blume and Muka [5] and published by NEMA.[6] It is based on a perceptual model developed by Barten.[7]

Table 1. Monitor Characteristics

Monitor	Lmax*	Cm(Center)
M-1	62fL	.37H/.51V
M-2	70fL	.54H/.72V
	35fL	.58H/.73V

* Lmax settings for Cm measurements

Monitor Calibrations

The monitor setups are summarized in Table 2. Setups 2-4 were compared to setup 1 and setups 6 through 11 to setup 5.

Table 2. Monitor Setups

Monitor	Setup	Lmin	Lmax .	Ambient
M-1	1	0.1fL	35fL	2 fc
M-2	2	0.015fL	107fL	2fc
M-2	3	0.1 fL	35fL	2fc
M-2	4	0.035	35fL	2fc
M-1	5	0.1fL	35fL	18fc
M-2	6	0.015fL	107fL	18fc
M-2	7	0.15fL	120fL	18fc
M-2	8	0.43fL	133fL	18fc
M-2	9	0.075fL	75fL	18fc
M-2	10	0.1fL	35fL	18fc
M-2	11	0.035fL	35fL	18fc

Imagery

Ten visible and ten radar images were used in the study. The hardcopy NIIRS ratings ranged from 4.4 to 6.7. The images were remapped following standard procedures and then a perceptual linearization LUT applied.

A sample of a Briggs target is shown in Figure 2. The numbers indicate the Briggs rating or score. The smallest target receives a rating of 90. The C-7 (dark and light squares differ by 7 command levels) and C-3 target sets (dark and light squares differ by 3 command levels) were used. Eight targets spaced across the command level range were evaluated. For each target, the analyst identified the smallest resolvable checkerboard and then rated the "quality" of the squares on a 1 to 5 scale where 1 indicates a sharp, well formed square and 5 indicates a "blob".

Evaluation Procedures

Eight imagery analysts (IAs) took part in the study. Experience levels ranged from 1 year to 30 years with a median of 12.5 years. Each analyst began the evaluation by providing decimal NIIRS ratings on the hardcopy imagery. They next provided decimal NIIRS and Briggs ratings on the M-1 monitor under the low ambient light condition. They then provided delta-NIIRS ratings relative to the M-1 for the other three (M-2) low-light level setups. All delta-NIIRS ratings were made at 2x magnification with bi-linear interpolation. Set-up order was counterbalanced. The same procedure was repeated for the high ambient light condition with decimal NIIRS and Briggs ratings being made on the M-1 monitor and then delta-NIIRS and Briggs ratings on the other seven M-2 setups. At the completion of the evaluation, each analyst completed a short questionnaire.

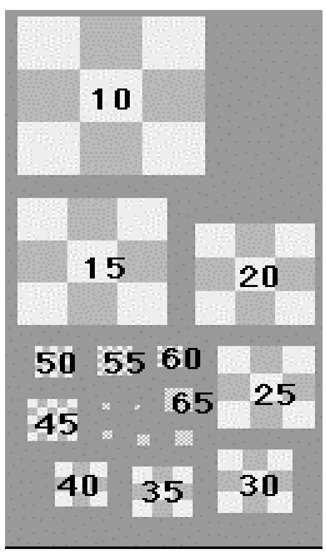

Figure 2. Briggs target sample.

Results

Outlier analysis eliminated data from one IA. Although the NIIRS ratings from that IA were highly correlated with the remainder of the group, the mean ratings from that IA were 10 times larger than the mean. Without that IA, average rater/group correlations were 0.54 for delta-NIIRS, 0.62 for decimal NIIRS, and 0.90 for Briggs ratings. The average delta-NIIRS standard deviation was 0.11 (less than normally observed) and the average Briggs score standard deviation was 0.8.

Briggs Rating Data

The effects of ambient light as a function of dynamic range are shown in Figure 3. The vertical lines indicate the 95% confidence interval for the means. For the sake of brevity, only C-7 data are shown. The C-3 data behaved in a similar manner. Ratings are always significantly higher under the dark ambient condition. Increasing dynamic range slightly mitigates, but does not overcome, the effects of bright ambient light.

The effects of varying minimum luminance under bright ambient conditions are shown in Figure 4. Figure 4 compares two Lmin values both having a 25.4 dB dynamic range. For the C-7 target, ratings are significantly higher with the higher Lmin value; differences for the C-3 target are not statistically significant. At the higher dynamic range shown in Figure 4, none of the Lmin values showed statistically significant differences. In dark ambient, none of the calibrations showed statistically significant differences in scores. Decreasing Lmin and increasing dynamic range had no effect relative to a calibration of 0.1 to 35 fL.

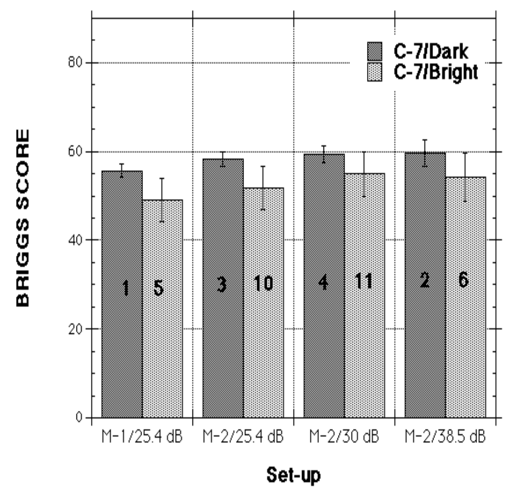

Figure 3. Effects of ambient light and dynamic range.

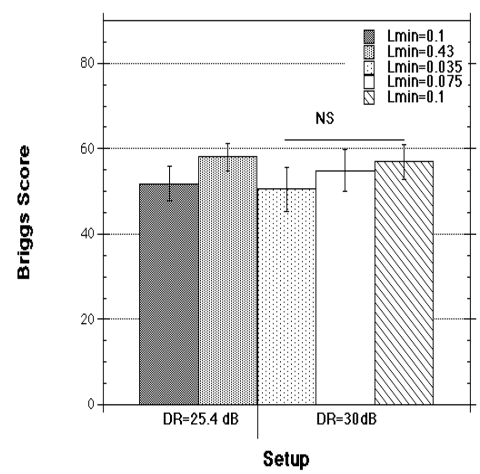

Figure 4. Comparison of Lmin values, bright ambient light, 25 and 30 dB dynamic range.

NIIRS Ratings

The effects of ambient light and dynamic range are shown in Figure 5 relative to hardcopy ratings. It is apparent that the bright ambient light condition significantly degraded interpretability for both types of imagery. The effect was greater for radar imagery. Increasing dynamic range alleviated, but did not totally overcome, the effects of bright ambient light.

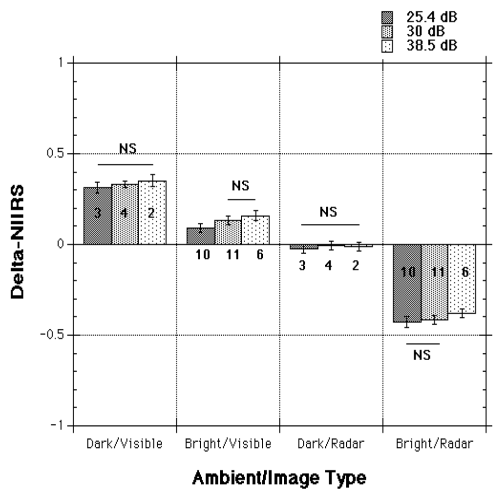

Figure 5. Effects of ambient light and dynamic range.

The effect of variations in Lmin are shown in Figure 6 for two different dynamic ranges. Increasing Lmin form 0.1 to 0.43 fL while holding dynamic range at 25.4 dB showed a statistically significant improvement in delta-NIIRS ratings. At 30 dB dynamic range, all of the increases except that from 0.035 to 0.75 for EO imagery were statistically significant.

Subjective Comments

At the completion of the evaluation, the analysts were asked to respond to a series of questions regarding the bright ambient presentations (which also used monitor set-ups at high luminance values). The analysts were asked to consider the displays they viewed in bright ambient light. More than half the IAs reported that one or more of the displays looked blurred, lacked detail in dark areas, and were hard on the eyes. Note that they had all seen displays in a darkened environment. Half the IAs believed some of the displays were too bright; none reported flicker.

Discussion and Conclusions

Results of the current study are consistent with the results of two previous studies.[3,8] Under bright ambient light, performance was degraded for both visible and radar imagery.

None of the calibrations evaluated overcame the loss resulting from the increase in ambient light. Increases in both Lmin and dynamic range were evaluated. Increasing Lmin from 0.1 to 0.43 (25 dB dynamic range) reduced the impact for both visible and radar. Increasing dynamic range from 25.4 to 38.5 dB helped both systems although for radar, the increase was less than that when Lmin was increased. Increasing Lmin from 0.035 to 0.15fL with a 30dB dynamic range significantly improved the interpretability of radar, but not visible.

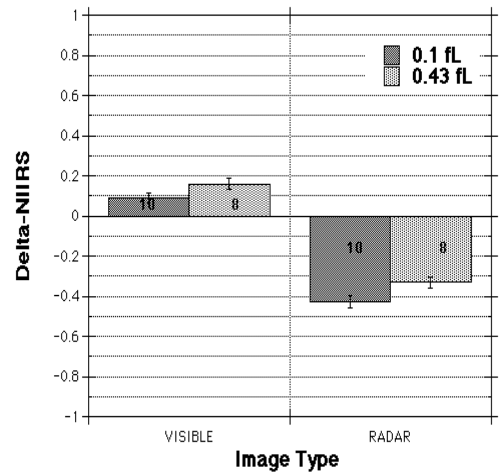

Figure 6. Effects of Lmin for 25.4 dB dynamic range.

Subjective comments provided by the IAs indicated that they were not happy with the calibrations used in the bright ambient light condition. Several indicated that the display was too bright, was blurry, lacked detail, and was hard on the eyes.

Under the darkened ambient light conditions, varying Lmin over the range of 0.015 to 0.1 fL had no effect on performance. Dynamic range was decreasing in parallel from 38.5 to 25.4 dB.

Results of this study have quantified the loss in interpretability at high ambient light levels with monitors that have been well calibrated. The loss ranged from 0.2 to 0.4 NIIRS. Poorly calibrated monitors might be expected to show even greater losses. Every attempt should therefore be made to perform critical exploitation tasks in a darkened environment. Although increasing Lmax and Lmin can mitigate the impact of bright ambient light, it can not overcome the loss. Further, the impact on mean-time-between-failure (MTBF) values of running at high brightness has not been quantified for all monitors.

Results of this study showed no advantage to running monitors at high dynamic ranges in a darkened ambient light condition. A previous study showed a performance threshold at approximately 22dB [9]. It thus appears that a dynamic range of 22 to 25 dB represents a performance asymptote, at least for the general luminance levels evaluated in this and previous referenced studies.

Acknowledgements

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