66.3: Visual Ergonomic Effects of Screen Gloss on LCDs

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Abstract

This study investigated if a requirement for screen gloss is needed in the TCO Requirements and was, therefore, targeted towards finding an acceptable reflex level. The results show that a glossy surface has an impact on the visual ergonomics, and for this reason we believe that a requirement is needed. Although, the results do not point to a single value that is better than another, so a selection for a requirement level has to be augmented with additional information. Such a discussion is given and 60 gloss units at 60 degrees (GU_{60}) was selected as the new requirement level for the TCO Requirements (TCO '03 and TCO '05).

1. Introduction

Recently computer displays and notebook computer that are designed with a so called glare panel have emerged on the market. This means that the screen area of the display could be highly glossy, together with most likely also the rest of the display. The shiny look of the display appeals to the costumers. Although reflections from surrounding light sources are a negative side effect, glossy screens are not all bad for the image quality. In some situations a glossy screen could be better for the visual ergonomics. A glossy screen often looks to have more saturated colours and higher contrast. However, the initial investigation that we have performed showed that the negative effects were larger than the positive effects experienced by the user[1], see Figure 1.

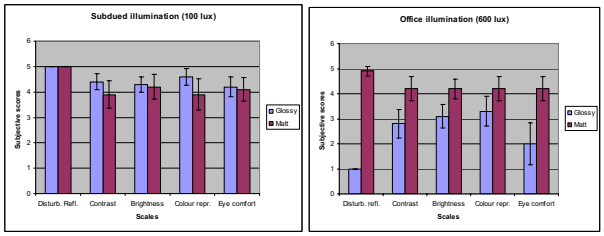

Figure 1: The subjective scores of the presence of disturbing reflex (1=no reflex, 5=strong reflex); the quality of contrast, brightness and colour reproduction (1=bad, 5=Excellent); as well as eye comfort. The left graph shows the scores in subdued illumination with no disturbing reflexes and the right graph shows the results in a more office like illumination where there are disturbing reflexes present.

Glare occurs when there is too much luminance in the wrong place[2], and is caused when a lamp or surface is brighter than the surroundings. The eye is being exposed to light which is brighter than what the eye is adapted to. It is more important to prevent glare for elderly people since they are more sensitive to glare. For instance the ability to adapt decreases with age and the lens in the eye gets cloudier with age, which makes the light scatter in the eye.

Today there is no requirement for front surface gloss on LCD-screens in TCO'03 Displays[3], and the primary goal for this work is to find if a requirement for screen gloss is needed in the TCO Requirements and also what the requirement level should be in that case. This study was targeted towards finding an acceptable reflex level. However only the effect of one reflection on the screen at a time has been evaluated, though; multiple reflections on the screen are common in many real life situations. Care has been taken to include working people at the ages where visual problems starts and are most frequent, that is, from about 40 to 65 years.

2. Method

A visual evaluation was performed on a group of test subjects to find how gloss affects visual performance and ergonomics. This visual evaluation contained three tasks which the test persons performed at an LCD screen while a disturbing reflex was placed on the screen (only two of them will be described in this paper, see Josefsson 2007[4]. There are a number of parameters that can be altered in this kind of experiment; some of these had to be kept constant. The size of the reflection is such a parameter and was therefore kept constant at a size corresponding to common sources of reflections, such as windows and indoor light sources. In this experiment the size of the reflection covering about 6 cm × 6 cm on the screen corresponds to a common light bulb of 60W with a diameter of 60 mm..

2.1 Apparatus

The experiment was performed in a room where the walls, ceiling and furniture had a neutral gray or slightly beige colour. The windows were covered with blackout cloth. An LCD screen, Samsung 21.3 inch widescreen SyncMaster 215TW, was used for all experiments. It was tested based on the TCO'06 as well as[5] extended tests for gloss and diffuse reflectance. The gloss value was measured to about 20 $GU_{60°}$, using BYK-Gardner mikro-TRI-gloss meter[6].

There are no screens on the market with such a variation in glossiness that this experiment needed and different screens would make the tests hard to carry out practically. For instance,. just calibrating the screens to the same colour temperature would be difficult. Therefore, filters were, used in front of the screen to make it more or less glossy. The filters used were a plastic film produced by Tekra[7] (Marnot XL Hardcoated Melinex Film) which had five different gloss levels (measured at 60°); with nominal values of 20 GU, 35 GU, 55 GU, 75 GU and 90 GU, thickness 0.2 mm. The filters were measured together with the screen with the BYK-Gardner gloss meter to obtain the actual gloss value, see Table 1

Table 1: Measured values for the plastic filters

	20GU	35GU	55GU	75GU	90GU
20°	7,3	16	28,6	48,2	59,5
60°	22,9	38,2	56,1	81,3	92,3
85°	15,4	23,8	40,7	56,8	63,6
Haze	15,6	22,2	27,5	33,1	32,8
Transmission	88,0%	89,2%	89,2%	89,2%	90,4%
Diffuse reflect.	14,2%	13,8%	13,9%	13,8%	13,9%

A passé par tout in grey cardboard with a diffuse reflectance of 50%, gloss values 0.7 $GU_{20°}$, 2.5 $GU_{60°}$ and 2.6 $GU_{85,°}$ were cut to fit the screen and a hole sized 19 cm×19 cm were cut out in the middle where the plastic filter were placed. This was done to prevent curving and therefore avoid additional uncontrollable reflections. An additional reason was that the plastic foil filters were smaller than the screen. A filter of each gloss levels were attached to the back of a passé par tout.

A LED (Light Emitting Diodes) lamp with 36 white diodes was used to create the reflex on the screen. The luminance of the lamp was measured to 85 000 cd/m^2 at 240 V. By the use of a lens system the rays from the lamp was collimated. In the real test the luminance was reduced to more realistic levels of about 9000 cd/m^2 by the use of grey filters. This made each diode visible on the screen. Also, a crossbar made of black tape was put on the lamp to make the visible reflex even more structured.

For displaying of test images the program Acrvqwin (version beta2)[8] was used.

2.2 Test subjects

The test group consisted of 20 healthy working people, 11 men and 9 women in the ages from 25 to 61 took part in the study. The average age was 44.6 and the median age was 45.5 years. They were divided into three age categories; 25-39, 40-50, 51-61. In the youngest age category there were seven persons, six persons were in the category 40-50 and the remaining seven was found in the oldest age category. All of the test persons worked at a computer every day, at least four hours a day and were used to looking at both pictures and documents containing text and numbers on the computer screen.

All of the test subjects had near visual acuity (50 cm) of 1.0 at with or without spectacle correction. Color vision was tested with an Ishihara test and was found to be normal on all participants. All subjects wore a grey cloth to standardize reflexes from clothes and avoid the so called “white-shirt-effect”. Information about the test was given both in writing and verbally.

2.3 Test setup

A controlled reflex of light was arranged to be visible in the centre of the display. The test setup was equipped with a head and chin rest to ensure that the reflex would be at approximately eye level for all test persons, and that the viewing distance 65 cm was constant for all test persons. The distance 65 cm was chosen based on the size of the monitor and since 50-70 cm is a common working distance for visual display work. The reflex was meant to be representative of a typical reflex in an office environment. Surrounding light was held constant during the test, about normal office illumination, 400 lux. Luminance of the screen with filters was set to 150 cd/m^2. Test set up is shown in Figure 2. The light source generating the reflex was placed at an angle of 20 degrees. Instead of putting the head and chin rest in the natural place right in front of the screen it was placed at the corresponding angle of 20 degrees. This angle was chosen because it is an angle that gloss is measured which could then be used to relate to the results of measured gloss at 20 degrees. This also had the effect that the diffuse reflectance was almost not present and the main reflection was specular.

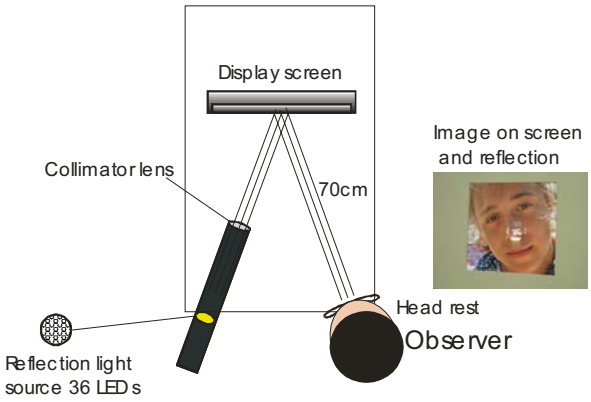

Figure 2: The test set up. The angle in which the light falls on the screen was 20 degrees, as well as the angle in which the observer was looking.

2.4 Tasks

The test persons had three tasks to perform at each gloss level: acceptable reflex, level of disturbance and a glare acuity test. Only the first two will be described here. The three tasks as well as the five gloss levels and the three reflex strengths were in randomized order for the different test persons. The images used in the test were chosen to be of different types and be neutral in content and at the same time sensitive to the question of interest. Total time for the experiment was about one hour.

2.4.1 Acceptable reflex

The subjects watched a series of nine pictures, as shown in Figure 3, and were asked to set a level of luminance such as it would be comfortable enough to have on the screen while working during a couple of hours. They were asked to set the level twice for each picture, one time starting with no visible reflex at all and the second time having a strong reflex from the beginning. To be able to set the acceptable reflex luminance on the screen the test subject adjusted a transformer in order to vary the amount of voltage to the lamp and therefore also vary the luminance of the reflex; the volt readings were then noted and later converted into luminance levels.

Figure 3: Pictures used in the experiment (referred to as: Black, Web, Face, Fuji TV, ,Grey, Chaplin, Text, Sea and White)

2.4.2 Level of disturbance

The subjects looked at the same pictures as in the previous test.

This time the reflex levels were set at three different levels to give one strong reflex (volt meter showing 89 V, luminance correspondence to about 9265 cd/m2), one weak reflex (volt meter showing 68 V, corresponding to about 108 cd/m2) and one where there was no reflex present at all (volt meter showing 0 V, luminance 0 cm/m2). The level where no reflex was visible was to see whether other sources in the surrounding area gave rise to unwanted disturbing reflexes e.g. the grey shirt. The pictures were presented in the program Acrvqwin. The pictures were shown for five seconds, after which a dialogue box popped up where the test subject could rate how disturbing the reflex was. The test was performed three times at each gloss level, one time for each of the fixed reflex levels. After each set of pictures the subject rated the screen contrast, colour rendering, picture naturalness and the overall impression of the pictures on category scales. The scales were from 1-10 and the subject rated all nine pictures together. This to see if any difference in contrast, colour rendering etc could be noticed between different gloss levels (these results will not be covered in this paper[4])

2.4.3 Information to test subjects

Before the experiment started, the test subjects were informed about how to perform the different tests. The information was both written and verbal. All tests were also run one time as a practice round before the actual testing to make the subjects acquainted with the test before the real one. In the practice round different pictures were used than in the actual experiment.

3. Results

All of the participants found the tasks easy to perform and most of the evaluations of the pictures were made looking in the middle of the picture, near the reflex. The diagrams presented below use gloss values at 60° even though the experiment itself was done at 20°. The graphs for 20° showed the same thing as the ones at 60° only dislocated accordingly to the difference in gloss, and since 60° is the standard for presenting gloss values we have chosen to

3.1 Acceptable reflex

A total of nine pictures were evaluated (Figure 3). The test persons adjusted the strength of the reflex to give an acceptable level. In Figure 4 (top) below the average luminance, taken over all test persons and pictures, of incoming light in the disturbance reflex is shown, together with the 95% confidence intervals (error bars).

Most of the spread could be explained by the impact of the different background pictures; this is seen in Figure 4 (middle) which shows that the acceptable strength of the incoming reflex is very dependant on the background image.

However, for the different gloss levels, the test persons have kept the light reaching their eyes constant for each of the picture backgrounds and thus adjusted the incoming light consequently, as shown in Figure 4 (bottom). For the pictures with the highest luminance, that is White, Text and Web, the accepted level of reflex was high as well. On the picture Chaplin with its rather "noisy" content the accepted level of reflex was also quite high. Black with its homogenous content gave the lowest accepted reflex.

It may seem that the persons accepts very strong reflex on text. But looking at the accepted contrast difference between the luminance of the peak of light in the reflex ($\Delta L = L_{tot} - L_{background}$) and the background luminance instead, it could be seen that the pictures with most important content also has the lowest contrast, i.e., Face, Text and Web. However, Text and Web have received its low contrast because of its high background luminance. The low contrast of the reflex on the picture White suggests that. On the other hand the Face has probably got its results based on picture content (Figure 5 top). presents these.

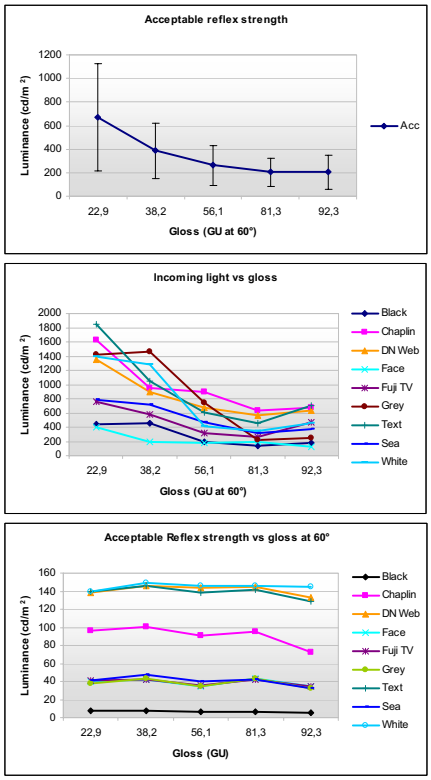

Figure 4: Average acceptable reflex luminance which is falling in to the display taken over all subjects and pictures (top) average acceptable reflex luminance which is falling in to the display for each image (middle) and average acceptable reflex luminance which is falling in to the display for each image which is reaching the eyes (bottom).

3.2 Level of disturbance

In this experiment the test persons indicated their perceived level of disturbance on a graded category scale using the following words: not visible (corresponding to score 1), visible but not disturbing (score 2), slightly disturbing (score 3), disturbing (score 4) and very disturbing (score 5). For the different reflex levels used; no light (0 cd/m^2), weak light (108 cd/m^2) and strong light (9265 cd/m^2). In Figure 5 (middle), the average disturbance level and 95% confidence interval taken over all test persons and at all picture backgrounds, is shown. A trend line is also marked out in the graph. The results showed, with the practically constant score for no reflex, that there were no disturbing reflexes from other light sources on the screen during the experiment. For the weak light reflex the level of disturbance increased with the gloss level. When it came to the strong light reflex level the reflex became so strong that the test subjects found it disturbing or even very disturbing for all gloss levels, however the trend line is slightly pointing upwards.

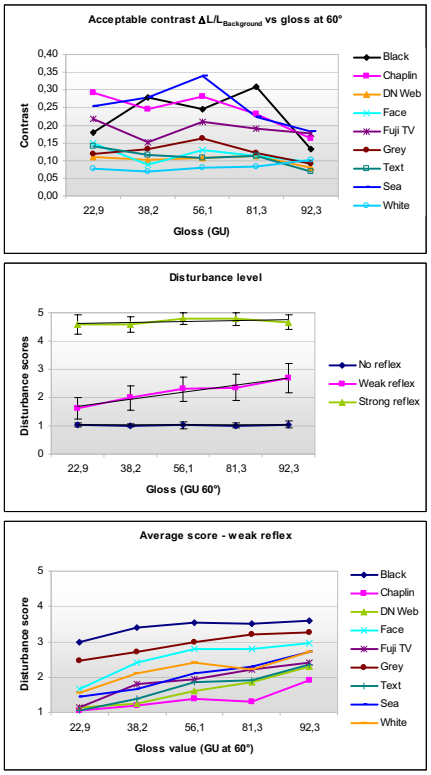

Figure 5: Acceptable contrast difference (top); average disturbance scores taken over all test persons at all backgrounds (middle); and average disturbance scores at weak reflex level taken over all test persons for each background pictur (bottom)

When looking at the average score for each of the nine pictures by itself, the result showed that the picture content had a great influence on the score, see Figure 5 (bottom). The pictures that got the lowest disturbance score for the weak reflex was pictures with content that could mask the reflex; Chaplin, and Fuji TV. The other pictures that got low scores were pictures with high background luminance; Web, Text and White, where the reflex got lower contrast due to the bright background. Pictures of a single colour, i.e. Black and Grey got the highest scores since their homogenous pattern could not mask the reflex. The picture Face did also get high scores even though it has content that could mask the reflex, but the fact that it is a picture of just a face most likely influenced the scores. A slight increase in disturbance score was also noticeable for all pictures at the different gloss levels.

For the strong reflex the pictures Face and Black had the highest disturbance scores; however the average scores were about the same for all pictures, probably because of the reflex being so strong that the test persons found it equally disturbing for all pictures and all gloss levels. No obvious differences in the disturbance score was found between the three age categories.

4. Conclusions

The motivation for performing this study was to see if it was possible to find a suitable level of gloss to set in the TCO Requirements. Looking at the test results they are not pointing towards an obvious requirement level for maximum screen gloss. Although, the results do show that a glossy surface has impact on the visual ergonomics, and for this reason we believe a requirement is needed. The acceptable level of incoming light decreased with increasing gloss level and the disturbance level is clearly increasing for the weak reflex case with increasing gloss level. The weak reflex case is probably the most realistic case, when the difference of gloss has any impact. If the reflex is as strong is in the strong reflex case, it is very likely that the user will do something about it, but not necessarily in the weak reflex case. However, the exact level has to be found with additional arguments. We do believe that some sort of anti-reflective coating is needed to reduce the impact of reflexes. This would lead to a gloss level of about 60 GU_{60}[9]. This is also consistent with the level of gloss of many CRT screens, which have a level of about 55 GU_{60}.

5. Acknowledgements

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6. References

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