

Reducing eyestrain from video and computer monitors

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Many of us work for hours each day in front of displays. It is very important to establish viewing conditions that minimize stress to our eyes. This note presents a number of steps that you can take to assure good monitor viewing conditions. This note does not address the equally important concerns of physical stress.

A number of steps can be taken with your display turned off:

- minimize reflections,
- control ambient light,
- establish a suitable *surround*, and
- establish a comfortable viewing distance.

Other steps are dependent on your display:

- adjust the *Black Level* (or *Brightness*) control,
- adjust the *Picture* (or *Contrast*) control, and
- on a color CRT, adjust convergence.

The principles explained here can be applied to improve the picture quality of computer displays and television monitors and receivers.

Contrast Ratio

Contrast ratio refers to the ratio of intensity between the darkest and lightest areas of a display. When you read a newspaper, the ratio of light intensity between the white paper and the black ink is typically fifty or more. Reading gray print on white paper – or black print on gray paper – is more difficult because the contrast ratio is lower. With a CRT display, many factors conspire to increase the intensity of blacks.

These effects reduce the contrast ratio of the screen, and this can induce eyestrain.

A black portion of a picture on your screen can never be made darker than the shade of your monitor's screen when its power is off.

Anything you can do to make the screen blacker will improve its contrast ratio, and consequently reduce eyestrain. Minimizing reflections and reducing ambient light are particularly important aspects of your physical viewing environment.

Minimizing Reflections

Your screen has a glass faceplate that reflects – into your eyes – light that originates behind you. Any reflected, bright object will interfere with your perception of the content of the display at the location where it is reflected.

To determine whether your screen suffers from reflections, turn off your monitor. You need not shut down your computer as long as your monitor has its own power switch. Sit in your normal working position and examine the dark screen for reflections – they will be distorted by the curvature of the screen. Try to arrange your environment so that you can see no intense light sources reflected from your screen. If you can't move the furniture, block your (reflected) view of the offending object with dark cardboard baffles.

Your monitor's screen may have an integral *antiglare* coating or treatment to minimize glare. A monitor with this treatment appears to have a very dark screen when it is turned off. You can attach an external antiglare screen to the front of your monitor, but some antiglare screens have such low light transmission that you may find that although they improve contrast, they reduce intensity of white to an unacceptably low level.

The flatter your monitor's faceplate, the less of a problem reflections are likely to be: a highly curved screen "collects" reflections over a wide angle behind you. A Sony Trinitron™ screen is cylindrical – having curvature about its vertical axis only – so it is not very susceptible to reflecting overhead lighting. Zenith Flat Tension Mask (FTM™) monitors have perfectly flat screens that suffer minimal reflections, however, these displays are not easily available, and not manufactured in sizes larger than 14 inches.

Controlling Ambient Light

When your monitor power is off, it may surprise you to find that one of the reflections that you see is your own! In order to minimize reflections of things in front of your screen other than lights – including your own face – it helps to reduce the general light level (ambient illumination). I recommend against using overhead fluorescent lights because I consider them too bright: excessively bright ambient illumination, in

addition to facilitating reflections, causes other problems that I will explain in a moment. However, exposure to a variety of lighting levels throughout the day is known to reduce stress, and medical research has concluded that exposure to bright light is essential for the body to maintain its 24-hour rhythms. When you take a break from your workstation – which are obviously necessary for reasons of physical health as well as visual – consider spending time in a brightly-lit area.

Establishing A “Surround”

Visual stress will be induced if – while you are watching your screen – your peripheral vision is exposed to light intensity brighter than the brightest regions of your display. A color scientist or video engineer uses the term *surround* to refer to the area that is perceived by your peripheral vision. In addition to disturbing your peripheral vision, a bright surround will necessarily increase your ambient illumination. Try to establish a visual surround that is quite a bit darker than the brightest white of your screen.

It is beneficial to have a visual reference to the outside world – such as a window to the outdoors – while working at your computer. With a window directly in front of you as you view the screen, your surround intensity is likely to be too high, but with a window directly at your back you are likely to suffer reflections. If you have a window, make sure you sit so that the window is far enough to your side that it does not impinge your peripheral vision, but not so far behind to reflect in your screen.

Can You See The Pixels?

If you can discern individual pixels on your screen, you are probably sitting too close to your screen for low-stress viewing. Our visual recognition skills – particularly reading – develop on the basis of recognizing shapes, not dots. When you look at the letter “V”, you should perceive two angled intersecting straight lines, not two jagged vertical elements or a collection of dots. The 1-pixel on/off checkerboard that is a default desktop pattern for many computers was actually designed to simulate 50% gray in an era when grayscale was rare. The pattern itself was supposed to be invisible.

A photograph is reproduced in a magazine as a *halftone*, a very fine pattern of dots of variable size. You don't view a magazine from a distance so close that you can discern individual halftone dots. For minimum stress viewing of your screen, you should work at a sufficient distance that pixels on the screen are not be discernible. I work at arm's-length from my 19-inch screen: in addition to its benefits for shape recognition, this viewing distance minimizes stress due to focusing at short distances for an extended period of time.

If you have trouble making out characters at a viewing distance sufficient to blend pixels into shapes, consider using a larger font for

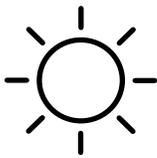
viewing on the screen. Page layout programs allow viewing at sizes larger than actual size. If your word processor has style sheets, you can create a style that has font sizes suitable for editing, and another (final) style suitable printing. You can then switch back and forth between the two styles without disturbing the contents of the document itself.

CRTs and LCDs

You can take the steps just described – minimizing reflections, controlling ambient light and establishing a surround – with your display turned off. These three steps apply both to the ubiquitous cathode ray tube (CRT) displays used in desktop workstations and also to the liquid-crystal displays (LCDs) now common in laptop computers.

LCDs do not suffer from any of the CRT afflictions to be discussed in the remainder of this note. For good LCD viewing, set *brightness* so that whites are displayed at a comfortable intensity. Then, set *contrast* so that blacks and whites are as distinct as possible – that is, so the displayed contrast ratio is sufficiently high.

Black Level



Once you have established good physical viewing conditions, the next step is to adjust the monitor's front-panel controls. Setting these controls is discussed in the companion document "*Black Level*" and "*Picture*". I will summarize that information in this section and the next.

The next few paragraphs describe how to set your *Black Level* control, whose icon is a circle surrounded by eight short radial lines. Some monitors have no user-accessible black-level control. Generally a monitor without the control is designed to require no adjustment, but a serious black-level problem on a monitor without a black level control may warrant a service technician to make internal adjustments.

Switch your monitor on, turn the *Picture* control all the way down, and display a picture that contains as much absolute black as possible. Use a black desktop background pattern, or a screen saver that displays mostly black. If you notice that the displayable central portion of the screen is distinctly lighter than the margins, or darkly colored, then your monitor has a black level problem. This may be corrected by adjusting the display's *Black Level* control. The black level control was historically – and misleadingly – labeled *Brightness*.

Adjust *Black Level* so that the black region of the picture is as black as possible, but just on the threshold of becoming visible. Avoid setting the control too low: this will cause the bottom range of brightness scale to be "swallowed", making your pictures appear muddy. Avoid setting it too high, which will reduce your contrast ratio.

Once you have set black level correctly, you may wish to put a piece of tape over it to avoid its being accidentally disturbed, and also to remind you that only the other control – *Picture* – should be adjusted when your viewing conditions change. You will not need to adjust *Black Level* again unless your monitor ages or you attach the monitor to a different computer or a different graphics card.

Picture



Once you have set black level, display a picture having lots of white, then use the control labeled *Picture* (sometimes misleadingly labeled *Contrast*) to set a comfortable maximum intensity. The icon for this control is a circle divided vertically into a black half and a white half. On a poor-quality monitor this control may interact with the black-level control, so you may need to go back and forth a few times to get the brightness you want while maintaining the correct black level.

Many factors reduce the performance of a CRT that is operating at a high brightness level. This is especially true for a computer display which, unlike a consumer television receiver, has a design that is optimized for sharpness at the expense of peak intensity. At high intensity your monitor will probably *bloom* objectionably, causing bright areas of the picture to defocus.

To avoid these impairments, operate your CRT at as low an intensity as is comfortable. This will be facilitated by the reducing ambient light and reflections according to previous sections of this note.

Your sensitivity to flicker increases as ambient illumination and picture intensity increases. An increased refresh rate reduces flicker, but since the refresh rate of a workstation is usually not adjustable, lowering your ambient illumination and reducing your display's intensity are probably the only methods you have available to reduce flicker.

Excellent contrast and brightness can be obtained if you set your CRT to white-on-black mode, in the manner of early video terminal displays. Human performance in reading and recognition tasks does not suffer from presentation in *inverse video*. However, visual stress is induced when the eye alternates its gaze between white paper and an inverse display, so this mode is generally not a good idea unless your task is totally dedicated to the display, for example if you are an air-traffic control operator.

Swimming

When a fixed information element on your display slowly changes position in a periodic manner, your display is said to be *swimming*. Swimming is generally caused by magnetic interference between the CRT and some external element. It could be that your office is next to a heavy-duty AC power distribution circuit, breaker panel or transformer. Unfortunately, the only practical solution to swimming is to move your

monitor. If all locations in your office exhibit the problem, then that monitor should not be used in that office: find a new monitor, or find a new office!

Swimming is often induced when two closely-adjacent monitors operate at different refresh rates. The only feasible solution is separating the monitors. In certain cases, external magnetic interference can cause a periodic change in the brightness of a color CRT, a condition known as *beating*. If beating is rapid enough – 10 or 20 times per second – it will appear as flicker. This effect, often mistakenly attributed to fluorescent lighting, can only be remedied as described above.

Color Convergence

The preceding discussion applies to both monochrome and color displays. A number of additional issues are specific to color CRTs.

Proper *convergence* is achieved when a color display places its constituent red, green and blue images in proper register across the entire display. Although the problems of gross misconvergence are obvious, a monitor that is even slightly misconverged will suffer reduced contrast ratio and poor apparent focus on black-and-white detail. For example, if the red, green and blue elements of the stem of a letter “T” are displaced from each other horizontally by an amount as small as the width of the stem, no part of the stem will reach a true black, causing a lower contrast ratio than if the monitor was converged. The “spread” in the stem in this example will cause it to appear poorly focused as well.

Adjusting convergence involves a series of internal calibration steps. Some monitors have a few convergence controls – such as V-STAT and H-STAT – on the front panel. When displaying detailed black-and-white information on your color screen, if you find that the red, green and blue elements do not align, and front-panel convergence controls are ineffective or unavailable, initiate a service call.

Magnetization of steel components of a monitor – such as its chassis – can interfere with the trajectories of the CRT’s electron beams and cause colors to shift, a condition known as *purity* failure. *Degaussing* refers to the act of demagnetizing the region near the front of the monitor, to remedy this situation. Modern monitors have degaussing circuitry that is actuated at the instant that the monitor’s power is applied. Although it is generally best for stability reasons to leave your color monitor powered on at all times, toggling the power off then on will initiate degaussing. You should do this any time you physically move or rotate a monitor more than ten or twenty centimeters.