



White Paper

Paper Mode of EIZO Monitors

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Introduction

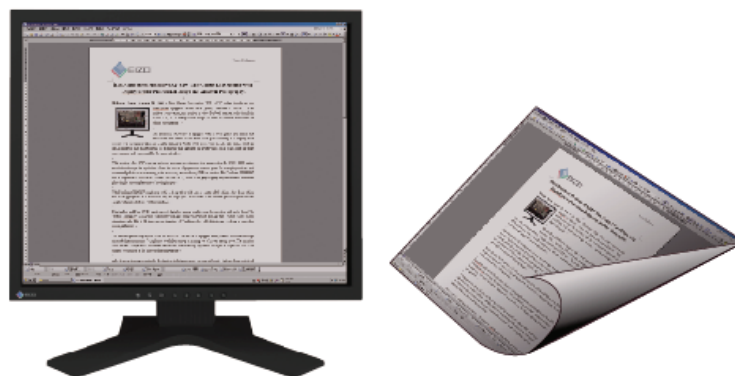
Reading documents and articles on a monitor has been common for quite some time. Recently, with the advent of IT technology, even books and novels are downloaded from the Internet and read on mobile devices. As you know, some manufactures develop mobile readers and they are sold them to all over the world. Under these circumstances, we think monitors can also to be used as reading devices for books or novels for some office or home users.

Are there any potential problems in reading books, novels or newspapers on a monitor for a long period of time? To find out, we conducted a survey of the relationship between fatigue and monitors for VDT (video display terminal) work under the supervision and guidance of an ophthalmologist and a VDT instructor in 2008. The results indicated a lesser increase in average near-point distance¹ for monitors set to similar brightness levels like papers. This suggests reducing brightness settings will reduce vision fatigue².

¹The closest distance at which an object can be brought into focus.

²Results and subjective perceptions vary from individual to individual.

Are there any differences between reading documents on paper and on a monitor? Some people say reading documents is easier on paper than on a monitor. This white paper explains differences between how documents appear on paper and on a monitor and also explains “Paper mode,” a new function of EIZO monitors that simulates the appearance of paper.



History of character recording

Era of stone

In ancient times, man invented languages to communicate. However, spoken language could not be recorded so man also invented characters and wrote them on stones, plates, etc. Characters engraved in stone last for centuries so man could pass them on to future generation as knowledge. On the other hand, stones have many drawbacks such as limited surface written area, heavy weight, and lack of mobility.

Era of paper

Man then invented paper to record characters. Paper is usually made out of trees and will not last as long as stone. On the other hand, compared to stone, paper is mobile and allows for significant increases in the quantity of characters that can be recorded.

Books are piles of papers and they were spread out all over world to share man's knowledge. We often hear talk of a paperless society, but books remain the primary method for recording at least for the present.

Era of electronic data

With the development of technology, electronic recording has begun to replace paper. Recording large amounts of information with a PC and monitor is much easier than using paper. All that is needed are a keyboard and enough hard disk drive space. With the Internet, electronic data can be shared around the world instantaneously. This information flow can not be done with books or papers. The era of electronic data is here but it is not without its drawbacks. We will explain these in detail below.

Differences between paper and monitors

As described before, some people say documents are easier to read on paper than on a monitor. In this section, we will explain the differences between paper and monitors.

Resolution Differences

Generally, the resolution of printouts is determined by screen ruling. Screen ruling means how many lines can be written per inch (lpi).

Resolution of monitors can be defined as dpi (dot / inch). Calculation from screen ruling (lpi) to monitor resolution (dpi) is as follows.

$$\text{Output monitor resolution (dpi)} = \text{Output screen ruling (lpi)} \times 2$$

Table 1 on the next page lists the necessary monitor resolution for each media.

A standard 24-inch wide monitor has only 94 dpi, and even a high resolution 21-inch medical monitor has just 154 dpi. This means that a monitor's resolution is lower than that of printouts.

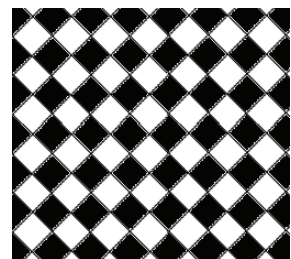


Fig 1: Screen ruling (line / inch)

Media	Screen ruling (lpi)	Necessary monitor resolution (dpi)
Newspaper	60 - 80	120 - 160
Book, Magazine	100 - 150	200 - 300
Brochure, Calendar	150 - 200	300 - 400

Table 1: Relation between screen ruling and necessary monitor resolution

Brightness differences

The monitor itself emits light so it is hardly affected by surrounding light or color. On the other hand, printouts (paper and photos) are affected by surrounding light or color. Thus, printouts in a brighter room appear bright and in a darker room appear dark. The type of paper also affects appearance. For example in the same ambient brightness the respective brightness of two different types of paper may appear to be different. This is because the reflection rates of the papers are different and helps explain why newspaper looks gray and copy paper looks bright. Table 2 shows general reflection rate of some papers.

The column on the right is equivalent paper brightness at general office luminance conditions (about 500 lx). Thus, newspaper is about 90 cd/m² and copy paper is about 110 cd/m².

Media	Reflection rate	Brightness at 500 lx
Newspaper	55 %	88 cd/m ²
Copy paper (recycled paper)	About 70 %	About 112 cd/m ²
PPC paper (100% virgin pulp)	About 80 %	About 130 cd/m ²

Table 2: Reflection rates of common paper and equivalent brightness

How about monitor brightness? Monitors keep getting brighter and brighter. Table 3 shows the maximum brightness of three current EIZO monitors. As you can see it is quite high compared to printouts.

Monitor name	Max. brightness
S2433W (24" widescreen monitor)	360 cd/m ²
EV2333W (23" widescreen monitor)	300 cd/m ²
SX2262W (22" widescreen monitor)	280 cd/m ²

Table 3: Maximum brightness of three current EIZO monitors

Differences in contrast ratio

The contrast ratio is explained in the following formula.

Contrast ratio = White area of the paper / Black area of the paper

Table 4 on the next page shows the contrast ratio of several types of paper as measured by an actual measurement device. The results showed that newspaper has a low contrast ratio compared to copy paper or photo paper.

Media	Contrast ratio
Newspaper	6.2:1
Copy paper (Recycled paper)	10.7:1
Copy paper (a)	31:1
Copy paper (b)	37:1
Photo paper	49:1

Table 4: Contrast ratios of common types of paper

How about monitor contrast ratio? Like brightness, the contrast ratio of monitors also keeps increasing. Table 5 shows the contrast ratios of several recent EIZO monitors. They, too, are high compared to printouts.

*Actual contrast ratio will be little lower because of reflection of ambient light.

Monitor name	Contrast ratio
S2433W (24" widescreen monitor)	1000:1
EV2333W (23" widescreen monitor)	3000:1
SX2262W (22" widescreen monitor)	1000:1

Table 5: Contrast ratios of three EIZO monitors

Differences of white (color temperature)

White color on the monitor consists of red, green and blue sub-pixels. Different colors can be displayed by controlling the balance of each sub-pixel. As you already know, the appearance of color on paper is affected by ambient light. Table 6 lists how several types of paper appear in a general office environment. x and y are color coordinates and can be calculated to specific color temperatures. Generally, the color temperature of a monitor is about 6500 K. In this experiment, measured papers had a color temperature of about 4000 K. This indicates that monitors are bluish compared to actual paper.

Note: color temperature can vary with the fluorescent lamps used in the office.



Fig 2: Printouts are affected by ambient light

Media	Color coordinate	Color temperature
News paper	$x=0.397, y=0.366$	3477 K
Copy paper (Recycled paper)	$x=0.394, y=0.400$	3828 K
Copy paper (a)	$x=0.383, y=0.386$	3999 K
Copy paper (b)	$x=0.386, y=0.388$	3936 K
Photo paper	$x=0.383, y=0.389$	4020 K

Table 6: Color coordinates and color temperature of paper in a typical office environment

Paper Mode

As we described in section 3, there are some differences between monitors and paper. By adjusting some of the

monitor's characteristics, documents on the monitor look similar to paper documents. We call this mode "Paper" mode. In this section, we explain the details of Paper mode.

Resolution

Resolution is a basic characteristic of LCD panels, so changing it is not easy. Paper mode does not increase the resolution of the LCD panel itself. To increase the apparent resolution, subpixel rendering software like ClearType from Microsoft and CoolType from Adobe is available.

Brightness

Many EIZO monitors come with an Auto EcoView (auto brightness adjustment) function. Auto EcoView adjusts the brightness of the monitor to the brightness of paper at the same ambient condition. As mentioned earlier, we undertook a survey of the relationship between eye fatigue and monitor use in 2008. The results indicated a lesser increase in average near-point distance for monitors set to brightness levels similar to paper. This suggests that reducing brightness settings will reduce vision fatigue. Paper mode simulates paper which has a 50 to 70% reflection rate. With Paper mode, when the ambient brightness changes, the brightness of the monitor also changes the way paper would.

Contrast ratio

In Paper mode, we need to think about newspaper and recycled paper, so the contrast ratio of the monitor is set to about 30:1. This is very low compared to the typical contrast ratio of monitors.

Electric paper is sometimes said to look like paper. Perhaps the reason is that it also has low contrast ratio like Paper mode.

White (color temperature)

In paper mode, we set the color temperature to between 4000 K and 5000 K. At first glance, the screen looks yellowish, but it more closely resembles the color of paper than the original color of the monitor.

Summary

In this white paper, we explained the history of character recording, the differences between monitor and paper, and the details of EIZO's Paper mode.

Monitors and paper have many differences like resolution, brightness, contrast ratio and color. Despite their differences, both are indispensable in our daily lives. Paper has advantages for reading documents. That is why we developed Paper mode to simulate paper.

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