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# Visual ergonomics of video-display-terminal workstations: Field measurements of luminance for various display settings

Francesco Leccese, Giacomo Salvadori, Michele Rocca *

*Department of Energy Engineering, Systems, Territory and Constructions (DESTeC) – Lighting and Acoustic Laboratory, School of Engineering, University of Pisa, Largo Lucio Lazzarino, Pisa, Italy*

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ABSTRACT

Electronic visual displays have shown a rapid technological evolution in the last two decades. With reference to the ergonomic requirements for video display terminal (VDT) workstations (ISO 9241), at an international level, attention is focused on the human–system interaction. With reference to visual ergonomics, the aim of this study is to assess luminance conditions through in-field measurements in order to evaluate: luminance and contrast ratios, luminance and contrast non-uniformities. The assessment was applied to widespread flat screen displays and repeated for fourteen combinations of Contrast–Brightness. The analysis carried out by the Authors shows the importance of realizing a simple and quick procedure to determine the performance levels of displays used in VDT workstations. The proposed assessment could be used as a practical tool for staff assigned to assess the risks arising from VDT use in the workplace within the Occupational Health and Safety Assessment Procedure.


## 1. Introduction

The introduction of computers has led to dramatic changes in work practices for many people. Today, activities such as reading, writing, and typing can be carried out without moving from a computer. This change in work practices has been accompanied by an increase in complaints about a number of health problems associated with working at video display terminals (VDT) [1]. Eye discomforts and also hand/wrist problems are often associated with VDT work. Results of different studies suggest that VDT users have increased the risk of developing eye discomforts, musculoskeletal pains and mental load [2–7]. As the work force becomes more and more dependent on computers, the need for proper and efficient design of VDT workstations [8] and also the need for risk assessment procedures [9] become increasingly critical.

With special reference to visual ergonomics, the main device of the VDT workstation is the monitor, because it represents the primary object of vision. The task of the monitor is to reproduce information; the quality of the information reproduced can sometimes be crucial for properly carrying out work tasks, especially if particular workstations are considered such as those used in mission critical control rooms (i.e. control rooms in airports, police stations, civil protection units,...).

As a visual object, a monitor is substantially different from a sheet of paper in many ways and viewing a monitor is much more visually demanding than viewing paper [10]. Unlike paper, a self-illuminated monitor, which is refreshed at a certain rate, and consists of different combinations of background and foreground causing different contrasting color objects that influence visual fatigue and can contribute to the outbreak of the Computer Vision Syndrome [11–14]. The objects displayed on a monitor consist of a series of pixel-based dots with decreasing brightness on their outer edges, thus making it hard for the eyes to focus. In addition, the viewing distance between the eyes and the computer screen is important and often not easily adjusted, especially if compared with the simple movement of a book to adjust viewing distance [12,14–18].

Monitors have undergone a rapid technological development and over the past 20–30 years we have gone from CRT phosphor monochrome displays to CRT color displays and then from LCD displays to the current LED displays. This evolution has resulted in an increase in the resolution and consequently in an improvement of visual performance and visual comfort as demonstrated by Ziefle [19]. Although displays realized with these new technologies can be considered photobiological risk exempt, as demonstrated by the extensive studies on the equipments commonly used in office workplaces [20–24], their effects on visual fatigue are still under investigation.

To obtain good visual performance while working at a VDT it is very important that luminance contrast and screen luminance are

* Corresponding author at: Largo Lucio Lazzarino, 56123 Pisa, Italy.
*E-mail address:* michele.rocca.au@gmail.com (M. Rocca).

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appropriate. Luminance contrast is an important factor in visual performance and display quality: the effect of luminance contrast on visual acuity and on the perception of the worker is huge, as shown in [25–29]. A significant improvement in both visual acuity and visual comfort can be obtained by increasing the luminance contrast, however this contrast must not exceed the value of 8:1, above which comfort falls again [8].

## 2. Requirements for electronic visual displays: International Standards

Electronic visual displays have had an extremely rapid technological evolution in the last two decades. They have reached increasingly higher performance levels and have changed the way that work is carried out in numerous professional jobs. For this reason, recently, with particular reference to those professional activities which require particular visual tasks (or time prolonged tasks) and high levels of precision, the need was felt to standardize the parameters to be evaluated in order to guarantee an ergonomic use on behalf of users. Currently, at an international level, attention is focused on the human–system interaction in light of the ergonomic requirements for office work with visual display terminals. In the EN ISO 9241-300 subseries standards, aspects of the ergonomics of the human–system interaction are treated in relation to the requirements of electronic visual displays. The subseries is structured as follows:

- Part 300 (2009): Introduction to electronic visual display requirements;
- Part 302 (2009): Terminology for electronic visual displays;
- Part 303 (2012): Requirements for electronic visual displays;
- Part 304 (2009): User performance test methods for electronic visual displays
- Part 305 (2009): Optical laboratory test methods for electronic visual displays;
- Part 306 (2009): Field assessment methods for electronic visual displays;
- Part 307 (2009): Analysis and compliance test methods for electronic visual displays;
- Part 308 (2008): Surface-conduction electron-emitter displays (SED) [Technical Report];
- Part 309 (2008): Organic light-emitting diode (OLED) displays [Technical Report].

This group of standards establishes the requisites that displays are required to meet during normal work use in order to guarantee adequate visual ergonomic performance.

In particular, EN ISO 9241-303 specifies the requirements for the ergonomic design of electronic visual displays stated as performance specifications, aimed at ensuring effective and comfortable viewing conditions for users with normal or adjusted-to-normal eyesight. On the other hand, EN ISO 9241-306 specifies optical, geometrical and visual inspection methods for field assessment of a display in various contexts of use according to EN ISO 9241-303. Finally, EN ISO 9241-307 specifies analysis and compliance test methods for electronic visual displays for a wide range of visual display tasks and environments.

In order to satisfy the human–system interaction, different requisites have been introduced, grouped into categories and shown in Table 1. From Table 1 it can be observed that the majority of requisites clearly refers to intrinsic display characteristics and to information display modalities, while some refer to the work environment (i.e. special physical environments) and others refer to user posture (i.e. viewing distance, viewing direction).

**Table 1**
Requirements for electronic visual displays (EN ISO 9241-303).

| | |
|---|---|
| Viewing conditions | Design viewing distance, design viewing direction, gaze and head tilt angles, displays for virtual images |
| Luminance | Display luminance, luminance balance and glare, luminance adjustment, illuminance |
| Special physical environments | Excessive temperatures, vibration, wind and rain |
| Visual artefacts | Luminance non-uniformity, color non uniformity, contrast non uniformity, geometric distortions, screen and faceplate defects, temporal instability (flicker), spatial instability (jitter), moiré effects, other instabilities, unwanted reflections, unintended depths effects |
| Legibility and readability | Luminance contrast, image polarity, character high, text size constancy, character stroke width, character width to height ratio, character format, between-character spacing, between-word spacing, between-line spacing |
| Legibility of information coding | Luminance coding, blink coding, color coding, geometrical coding |
| Legibility of graphics | Monochrome and multicolor object size, contrast for object legibility, color consideration for graphics, background and surrounding image effects, number of colors |
| Fidelity | Color gamut and reference white, gamma and grey scale, rendering for moving Images, Image Formation Time (ITF), spatial resolution, raster modulation or fill factor, pixel density |

EN ISO 9241-307 describes methods of analysis and testing to implement for evaluating all the requirements for electronic visual displays. This standard refers to both field and laboratory assessments and furnishes specific indications in relation to display technology. In particular, the displays dealt with are Cathode Ray Tube (CRT) Displays, flat panel Liquid Crystal Displays (LCD), Plasma Display Panels (PDP), front screen projection visual displays with fixed resolution and emissive, reflective or transflective LCDs for handheld devices. In this standard, displays are further subdivided according to whether they are anisotropic displays (luminance, contrast and color vary with viewing direction) or isotropic displays and whether the information which is predominantly displayed during the execution of the visual task is artificial (objects and scenes that do not have originals in our world, for example, text, graphical signs, symbols, etc.) or real (imaging of objects and scenes that do have existing originals in our world).

## 3. Display luminance

In this paper the Authors are particularly concerned with the analysis of luminance through in-field measurements in order to evaluate the following requisites: luminance ratio, contrast ratio, luminance non-uniformity and contrast non-uniformity. For this reason, together with a specific analysis of the display itself, it is necessary to conduct a simultaneous analysis of the workstation's detailed lighting (i.e. the desk) and, more in general, the lighting of the work environment (i.e. the background walls). Analysis of the work environment lighting may be developed through (refer to EN ISO 9241-5 and EN ISO 9241-6) luminance measurements (i.e. on desk, computer keyboard, surfaces behind the display), calculation of luminance ratios in both static and dynamic visual conditions, illumination measurements (on the various work planes involved in the visual task), calculation of luminance average uniformities on the various surfaces [9,30]. Furthermore, it is necessary to assess postural ergonomics in relation to the workstation and to the entire work environment. For example, in work environments in which the interaction with a display is carried out with an erect torso, the viewing angle between line of sight and display should be in the range 0–40° and the user head tilt angle should not be greater than 25°.