ELSEVIER

Applied Ergonomics 40 (2009) 69–81

APPLIED ERGONOMICS

www.elsevier.com/locate/apergo

A visual ergonomic evaluation of different screen types and screen technologies with respect to discrimination performance

Sophie Oetjen, Martina Ziefle*

RWTH Aachen University, Jägerstraße 17–19, D-52056 Aachen, Germany

Received 29 June 2007; accepted 26 January 2008

Abstract

An increasing demand to work with electronic displays and to use mobile computers emphasises the need to compare visual performance while working with different screen types. In the present study, a cathode ray tube (CRT) was compared to an external liquid crystal display (LCD) and a Notebook-LCD. The influence of screen type and viewing angle on discrimination performance was studied. Physical measurements revealed that luminance and contrast values change with varying viewing angles (anisotropy). This is most pronounced in Notebook-LCDs, followed by external LCDs and CRTs. Performance data showed that LCD's anisotropy has negative impacts on completing time critical visual tasks. The best results were achieved when a CRT was used. The largest deterioration of performance resulted when participants worked with a Notebook-LCD. When it is necessary to react quickly and accurately, LCD screens have disadvantages. The anisotropy of LCD-TFTs is therefore considered to be as a limiting factor deteriorating visual performance.

Keywords: Notebook-LCD; Discrimination Performance; Anisotropy

1. Introduction

The private and public need for electronically displayed information has increased considerably and continuously for a fairly long time. In order to assure high productivity, it should be focused on the visual quality of electronic displays and the ease with which they allow visual information to be processed. Improvements in screen technology lead to a considerable change of the quality of electronic displays and display types. Nevertheless, the underlying ergonomic questions did not change: How can it be assured that working with electronic screens is possible without difficulty and that efficient visual processing of information is facilitated?

Visual ergonomic studies were concerned with the evaluation of electronic displays and aimed at identifying possible shortcomings of current display design. The criteria for the suitability of displays for presenting information were users' productivity in terms of speed and accuracy of visual processing as well as the emergence of visual strain (e.g. Gould et al., 1987a, b; Dillon 1992, 2004; Schlick et al., 2007; Sheedy and Bergstrom, 2002; Ziefle, 1998; Ziefle et al., 2005). Even though the studies yielded a solid visual ergonomic knowledge with respect to the displaying of electronic information, technical developments and improvements necessitate the need to continuously evaluate new technologies with respect to their actual benefit for human performance. This regards, for example, the impact of different text factors (e.g. structure, format, and breadth of electronic information) as well as display factors (e.g. contrast, resolution, image quality) (e.g. Dillon et al., 2006; Farrell, 1987; Oetjen and Ziefle, 2004, 2007; Qin et al., 2006; Sheedy et al., 2003; Vaughan and Dillon, 2006; Ziefle et al., 2003). Also, the impact of visual and cognitive demands that are imposed by different task types and the effects of prolonged on-screen reading still receive attention (e.g. Gröger et al., 2005; Schlick et al., 2007; Stone et al., 1980; Ziefle, 1998).

*Corresponding author. Tel.: +49 241 8096130; fax: +49 241 8092318.
E-mail addresses: Sophie.Oetjen@psych.rwth-aachen.de (S. Oetjen), Martina.Ziefle@psych.rwth-aachen.de (M. Ziefle).

0003-6870/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apergo.2008.01.008

Another prominent research issue refers to the question, which screen type benefits or disadvantages visual performance. The comparison of different display types received special attention lately as screen technology changed. While a few years ago, the cathode ray tube (CRT) was the state-of-the-art technology and was excessively studied (Schlick et al., 2007), the liquid crystal displays (LCDs) are replacing CRTs more and more. LCDs with thin film transistor technique (LCD-TFTs) seem to overcome many disadvantages of the CRTs. Beyond others, the most significant advantage is their suitability for mobile devices. For this reason, they are not only used in small screen devices like digital cameras and mobile phones, but also play an important role in computer notebooks. Notebook computers are continuously replacing stationary desktop computers and should be focused in the ergonomic evaluation of electronic displays (Kirsch, 2004).

Although distribution and purchase rates of notebook computers are increasing (BITKOM, 2007), to our knowledge no visual ergonomic study was concerned with the visual quality of Notebook-LCDs so far. Whenever notebooks are considered in ergonomic studies, mostly the specificity of hardware components (e.g. input devices, Sutter and Ziefle 2005; Armbrüster et al., 2007) or the specificity of users' sitting posture and characteristics of work places received attention (e.g. Harbison and Forrester, 1995; Saito et al., 2000). As the trend is heading towards a steady increase in mobility, there is a considerable need to learn about the suitability of the visual conditions that are present in Notebook-LCDs. This is the topic of the present study.

To achieve valuable results, a two-step procedure was realised: the first step was to physically measure the visual quality of different screen types and screen technologies. To do so, a standardised measurement procedure was applied that allows the objective, replicable and reliable comparison of the physical features of different screen types. The second step in the analysis of the suitability of Notebook-LCDs was to determine the visual discrimination performance of normal screen users. Here three screen types were compared: the screen of a Notebook-PC, an external LCD and a CRT.

2. Characteristics of the screens and electronic displaying

From a visual ergonomic perspective, the CRT and LCD screen technologies have different advantages and disadvantages. This results in different display-specific performance benefits and drawbacks. These are summarised in the following section.

2.1. Cathode ray tube displays

A characteristic visual feature of CRT screens is a flicker sensation caused by low refresh rates. Many studies have examined the impact of refresh rates and screen flicker, and revealed that it is a major source of performance decrements (e.g. Menozzi et al., 1999, 2001) and visual fatiguing (e.g. Jaschinski et al., 1996). It can even be responsible for the emergence of migraines (e.g. Boschman and Roufs, 1994; Küller and Laike, 1998). A screen flickering at 50 Hz leads to a significant disturbance and a deterioration of visual performance compared to 100 Hz-screens. The performance decreases even more, when the time on task is prolonged. However, increased refresh rates lead to an increase in performance and it can overall be stated that rates of about 100 Hz facilitate a reasonably good performance (e.g. Ziefle, 2001). A second important disadvantage of CRT displays is the bulky format and relatively high weight. These characteristics also have an impact on visual performance, because the admeasurements and space restrictions on conventional computer and office desks (about 80 cm depth) do not allow users to change the position of their screen easily and flexibly. Thus, it is impossible to adjust the viewing distance to the screen and meet individual accommodation needs of the users (users differ considerably in their personally preferred viewing distances and their optimal focal distances, e.g. Heuer et al., 1991; Ziefle, 2003). Beyond visual characteristics, it should be mentioned that CRTs also have a certain amount of radiation, what may be especially important when more than one CRT is used in a small space.

2.2. Liquid crystal displays

The LCD technology seems to elegantly overcome the disadvantages of the CRT screens. LCDs are lightweight and small, and can therefore be individually positioned on computer desks. Further important advantages are that LCD screens run flicker free, provide higher luminance levels than CRTs, and that they can be used in mobile devices. Notebook-LCDs have a lower threshold voltage than their external counterparts. This leads to less complicated electronics, the possibility to use smaller components and an even lower weight and footprint. Furthermore, the energy consumption can be reduced and the operation time of the batteries can be extended. Lower threshold voltages can be realised because the liquid crystal mixtures in Notebook-LCDs are slightly different from the ones used in conventional external LCDs (Heckmeier et al., 2002).

Apart from these advantages, the main drawback of LCDs is that the visibility of information depends upon the viewing angles. Information cannot be seen perfectly when it is not displayed in the centre of the screen or when the user is not sitting directly in front of the screen but looks at it from aside. Under off-axis conditions, the light from the display has a different direction and the users can perceive rays of light that should not be seen. In physical terms, the distribution of luminance over the screen's surface is not constant but differs depending on the point of view. This specific property of LCD screens is called anisotropy. According to ISO 13406-2 (ISO, 2001), a display is called anisotropic when it shows a deviation of luminance of more than 10% depending on the target location or the