Displays 35 (2014) 101–109

Contents lists available at ScienceDirect

Displays

journal homepage: www.elsevier.com/locate/displa

Selection of character/background colour combinations for onscreen searching tasks: An eye movement, subjective and performance approach

Debojyoti Bhattacharyya, Bodhisattwa Chowdhury, Tirthankar Chatterjee, Madhusudan Pal, Dhurjati Majumdar *

Ergonomics Division, Defence Institute of Physiology and Allied Sciences, Defence Research & Development Organization, Lucknow Road, Timarpur, Delhi 110 054, India

ARTICLE INFO

Article history:
Received 3 April 2013
Received in revised form 19 February 2014
Accepted 22 March 2014
Available online 4 April 2014

Keywords:
Character/background colour combination
Eye movement variables
Mental workload
Legibility rating
Searching time
Performance

ABSTRACT

The aim of the study was to investigate the effect of various character and background colour combinations on cognitive performance during onscreen searching tasks and to identify the best combinations with a multimodal approach of physiological (eye movement recording), subjective and performance data collection. In the absence of proper character and background colour combination the optimum performance for a cognitive task is greatly affected which in turn affects the productivity of the individual worker or communications among the operators working under the same network through information sharing. This study was designed by selecting six colours, i.e., white, black, yellow, red, blue, and green and subsequently combining them to 16 character and background colour combinations for a searching task. Right and left headed arrows were used as the character for the searching maneuver. Forty-four ($N = 44$) volunteers participated in the experiments. Various eye movement variables, legibility rating scale, NASA-TLX questionnaire, searching time and percentage of error were recorded. Subjects performed better wherever a good contrast was there because of a high legibility. A poorly contrasted display affected the physiological variables as well as subjective responses to negative directions. Among the combinations of dark character/light background, blue and red character on white background is highly recommended; and while that for light character/dark background, white is found to be the best character on blue and green backgrounds.

1. Introduction

Visual search is an effective tool in everyday life to find faces, objects and information of interest. Our purpose of visual search varies as per situation. Operation in the air traffic control (ATC) panel and tacking harsh situations in the battle field demand much higher cognitive resources as per the frequently changing current need. Military workstations are high density workstations in terms of higher mental demand under various critical conditions. These critical conditions are depicted in the C^4ISR loop, i.e., command, control, communication, computer, intelligence, surveillance and reconnaissance. Each action of this loop is having their specific cognitive characteristics. Moreover, these operations are being performed in a digital environment where information is displayed with various character and background colour combinations. It has been shown that proper trade-off between the application of good display principles and well recognized limit of human cognitive processing offers a better situational awareness and proper decision making [1].

In this context it is important to mention that physical characters like display type, character/background colour combination, shape, size of the font, speed of dynamic display, illumination level, viewing distance, etc. play a critical role in legibility and thus determining the subjects' performance [1–5].

Careful selection of colours in the designing of visuals on display is of critical importance for optimum performance [2–5]. Use of colour is always purposive, e.g., red colour is always used to display some caution messages like in traffic signal to stop the cars, and a black font printed on a white background for regular reading activities. Use of proper colour combination ensures an enhanced effectiveness of the display that may ultimately lead to faster performance rate [6,7]. On the other hand poorly chosen colour leads to decreased performance and probably increases the risk of visual fatigue [8,9]. Many researchers outlined that

* Corresponding author. Tel.: +91 11 23883014, +91 11 23935745.
E-mail addresses: rajdeb8206@gmail.com (D. Bhattacharyya), bodhi.chow@gmail.com (B. Chowdhury), tirthankar_06@rediffmail.com (T. Chatterjee), madhudipas@gmail.com (M. Pal), majum55@yahoo.com (D. Majumdar).

http://dx.doi.org/10.1016/j.displa.2014.03.002
0141-9382/

the overuse of colour may elicit various psychological responses which will eventually affect the performance [10,11]. However, Pastoor [12] mentioned that colour combination has no effect on the search time. Hence, colours must be chosen not only by considering the experimenters or users preference but also by considering the cognitive constraints of the users [2]. Empirical evidences showed that primary colours-red, green and blue offer a higher level of accuracy in performance than other non-primary colours. Matthews et al. [13] suggested that red and blue both can be used as stimuli either alone or in combination for better performance. Kwallek and Lewis [14], Stone [15] have recommended that red is preferable compared to blue or green during cognitive task performance. Other researchers have proposed the opposite [16,17]. In another important study Mehta and Zhu [18] conducted a series of six experiments and concluded that blue is recommended as background for any creative work and with red background some vigilant work can be performed. Greco et al. [4] found that best legibility can be achieved by displaying information on bright background with dark font (black and dark blue) on computer screen as well as on projectors. Other researchers like Legge et al. [19]; Shieh and Lin [20] reported that white/black background/text combination as the best. Greco et al. [4] stated that among the combinations of light font on the dark background, green, brown, black and blue were the best background, whereas red is the worst. On those background white was the preferred font colour.

Most of studies related to the choice of proper character and background colour combinations have drawn their interpretation depending upon the subjective response by applying various questionnaire methods, rating scales, or by recording the performance and error in identifying the targets. Evidences for interpretations based on various eye movement variables are least documented till date. Recording of eye movement variables during a cognitive task performance will help to assess the cognitive demand of the respective task. Eye movement activities like changes in pupil diameter, blink frequency, fixation, fixation frequency, saccadic behaviour are known as good predictor of searching efficiency as well as imposed cognitive load. Considering the above scenario a study was designed for the selection of proper character and background colour combinations for onscreen searching task which impose least cognitive load with improved performance.

2. Material and methods

2.1. Subjects

Forty-four young Indian adults (Age −26.2 ± 4.3 years, height −164.26 ± 9.37 and weight 64.0 ± 12 kg) were the volunteers of the experiment. They were all post graduate researchers and young scientists. The present study was conducted in accordance with the ethical principle expressed in the declaration of Helsinki and all the participants provided informed, written consent before their participation in the experiment. A thorough description about the purpose and protocol of the experiment was given to the subjects. All the subjects were having normal or corrected-to-normal vision with a visual acuity of 6/6 and chosen for not being colour blind using Ishihara 1–17 colour plates. The candidates who had problems to identify the numbers in most of the colour plates were not included for the experiments. All the experiments were carried out at the first half of the working hours between 0930 h to 1300 h. Each subject invested about 40–50 min for the whole experimental protocol.

2.2. The environmental specifications for the experiment

All the experiments were carried out in a laboratory which is specifically dedicated for the eye tracking system. The room temperature and relative humidity were maintained at 26 °C and 50% respectively [21] and was measured by a thermo-hygrometer (HTC-1, China). Room illumination level was maintained between 450 and 500 lux [22] and was measured by digital lux meter (HTC, LX 103). Horizontal distance from the screen to the seated eye position were kept between 60 and 70 cm considering compatibility between the subjects' body dimension and proper viewing of the displayed information on the screen. The room was made noise attenuated to provide a calm and quiet environment to the subjects so that they can perform the task with concentration. As the eye-tracker functions in the near infrared light spectrum few important precautions were taken such as, blocking the entry of natural light by covering the windows, avoiding the usage of incandescent bulbs, halogen bulbs and by using fluorescent bulbs. The furniture, equipment made up with iron, steel, copper, aluminum were discarded from the experimental room as these metals are known to create artifact in the magnetic field of magnetic head tracker. Only wooden chairs were provided for the sitting purpose.

2.3. Calibration of the eye-tracker

A binocular eye tracker [Model No. HS-BN6.1, M/s Applied Scientific Laboratories (ASL) USA] with head mounted optics and magnetic head tracker (ascension flock of birds processor with transmitter and receiver unit) was used to record the eye movements. The eye-tracking system was calibrated for each subject before starting the recording session. A set of numbers from 1 to 9, arranged in 3 × 3 array were displayed in the computer screen with 1 at the top left of the screen and 9 at the bottom right of the screen. The subjects were asked to fix each numbers sequentially form 1–9 by gazing at the respective number. By doing this a scene plane boundary was constructed within which all the eye movement activities were recorded. Any activity outside this boundary was automatically excluded. The data were sampled at 120 Hz. Data recorded from the left eye were considered for further analysis. The scene plane calibration and experimental stimulus delivery were both carried out on a HP LP2465 24 in. TFT monitor with a viewing angle of 178°H/178°V and resolution of 1920 × 1200 pixel (aspect ratio 16:10).

2.4. Selection of colours

Six colours, namely white, black, red, blue, green and yellow were chosen from Microsoft® PowerPoint® colour palette for the present study. These colours were chosen because of their frequent usage in every aspect of life. Black and white combination is popular reading medium and red, green, blue, and yellow are the fundamental colour sense which cannot be represented as mixture of two or more colours [23,24]. Jacobs and Suess [25] described that red, green, blue and yellow are four psychological primary colours to evoke the anxiety state and this finding is well agreed with the physiological studies attempted by Jacobs and Hustmyer [26] and Gerard [27]. The hue, saturation and luminance (HSL) value of these colours are given in Table 1.

Table 1
The hue, saturation and luminance (HSL) value of the selected colours for the present study.

Colours	Hue	Saturation	Luminance
White	170	0	255
Black	170	0	0
Red	0	255	96
Green	85	255	26
Blue	156	255	48
Yellow	42	255	128