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Visual Strain and Lighting Preferences of VDT Users Under Different Lighting Systems

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Lighting influences users' visual strain and well-being. Therefore creating lighting that ensures visual work conditions do not result in visual fatigue is a preventive activity. The aim of the study was to model different lighting systems for visual display terminal (VDT) work and to determine their influence on users' visual strain and preferences. The results of the study showed that visual fatigue was lowest for indirect and compound lighting systems. On the other hand, in general, direct lighting realized by "dark-light" luminaires was the most preferred lighting system. Some interesting differences related to age, gender, and VDT work experience were found. On the basis of the obtained results lighting designers can be provided with some guidance.

VDT users lighting systems visual fatigue lighting preferences

1. INTRODUCTION

An evaluation of working conditions and an observation of changes within a range of hazards related to the working environment make it possible to undertake preventive activities and to adopt and carry out an adequate policy aimed at improving working conditions. The lighting of workplaces is usually considered an environmental and physical factor in the working environment. It is obvious that workers can perform visual tasks safely under adequate

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lighting conditions. Additionally lighting influences users' visual strain and well-being. Therefore creating lighting that prevents risk at workplaces and ensures that visual work conditions do not result in visual fatigue is a preventive activity.

It is well known that visual fatigue during visual display terminal (VDT) work is still common. A study of VDT operators in Poland showed that 90% of complaints were related to eyesight (Kamieńska-Żyła, 1993). Other studies (Leavitt, 1995; Pickett & Lees, 1991) reported that 75 to 85% of all VDT users complain of eyestrain symptoms. One of the main environmental factors that is suspected of contributing to a rise in visual fatigue is lighting (Anshel, 1998; Bergqvist, 1984; Dainoff, 1982; Pickett & Lees, 1991; Smith, Cohen, & Stammerjohn, 1981; Wolska & Świtula, 1999).

The goal of illuminating engineering is not only to avoid any possible dangers or other negative results, but actually to promote health in the meaning of the World Health Organization (WHO) definition: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity[1]." That means lighting should ensure a luminous environment that is human-friendly and appropriate for the performed visual tasks. Thus, visual strain should be minimized and well-being ensured during visual work under a given lighting system. Visual work is inseparably connected with visual fatigue, but the kinds of symptoms and their intensities depend on different factors. A review of office lighting environment in Poland (Kamieńska-Żyła, 1993) and in Japan (Kanaya, 1990) showed that visual working conditions, especially at VDT stands, are far from perfect. In many offices the introduction of VDT equipment were not followed by changes in lighting. On the other hand even if there were changes in lighting, they did not necessarily lead to the users' acceptance of the new lighting. Çakir's (1991) longitudinal study (1978–1990), which assessed lighting in offices and at VDT stands in Germany, showed that artificial lighting was far from promoting health and well-being in the spirit of the WHO definition of health. Çakir (1991) concluded that technical improvements in office illumination would not lead, over the years, to an increase in the level of acceptance for artificial lighting.

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[1] Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19–22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948. Retrieved July 28, 2003, from http://www.who.int/about/definition/en/

The variety of lighting realizations for a given room, which ensure compliance with lighting requirements for VDT work, give lighting designers an opportunity to create a wide range of luminous environments. But this does not mean that all of them influence the users' visual strain and well-being in the same way.

The purpose of the present study was to model different lighting systems for VDT work and to improve knowledge in the field of choosing best lighting systems for VDT stands taking into consideration users' visual strain and preferences.

2. METHOD

2.1. Participants

The group consisted of 44 participants (15 women and 29 men) aged 17–37 with a mean age of 22.25 years. The participants were selected according to the criteria of age (under 40 years old), eye state (no known visual defects, visual acuity ranging between 1.0 and 1.5 on Snellen charts for distance, with corrective lenses if needed, spherical refractive errors lower than ±3.5 Dsph, astigmatism lower than ±0.5 Dcyl, and no systemic or neurological diseases), and VDT work experience (novices and professionals). The participants' VDT work experience was evaluated during pre-study group selection on the basis of an interview. The volunteers had to do a list of specially prepared VDT tasks and to fill in a questionnaire. As a result the group was composed of 22 novices and 22 professionals. All participants volunteered to take part in the study and underwent training in VDT work before the experiments. They became familiar with the visual task simulated by a computer program.

During the study each participant took part in four experimental sessions, one session for one lighting system.

2.2. Visual Task

The visual task was simulated by a computer program and consisted of eight Landolt tests (four with negative and four with positive polarity on the screen). Each test consisted of 352 white or black rings respectively. There were two kinds of Landolt tests:

- a step-by-step test, in which each of the eight possibilities of gap localization had to be defined for 352 rings on the screen (Figure 1);

- an option test, in which rings only with three gap localizations (indicated in the corner of the screen) had to be found (from among 352 rings) and marked. The colour of the marked rings changed and mistakes could not be corrected.

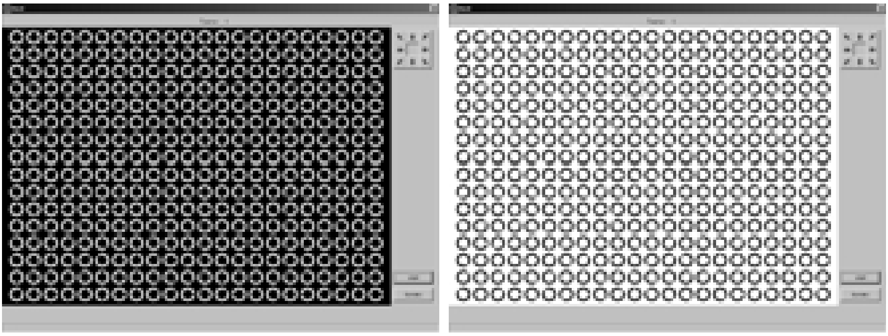

Figure 1. Presentation of a step-by-step test for positive and negative polarity on the screen.

Gap localizations were indicated by clicking (with a mouse) an arrow appropriate to the position of the gap. The possible eight positions of arrows were placed in the upper right corner of the screen (see Figure 1). Both kinds of tests were prepared for positive and negative polarity and each of the eight tests had a different ring distribution on the screen.

Participants performed the visual task for 1.5–2 hrs.

2.3. Lighting Conditions

Experiments were carried out in laboratory conditions for the following lighting systems (see Figure 2) suitable for VDT work:

- direct-indirect (DI-L) in the form of soft-light fluorescent luminaires ABML (Ridi, Germany) 2 × 58 W,
- direct (D-L) in the form of dark-light fluorescent luminaires XRD (Zumtobel, Austria) 2 × 36 W,
- indirect (I-L) in the form of uplight fluorescent luminaires TCS 663 (Philips Lighting, Poland) 2 × 58 W,
- compound (C-L), general and task lighting, with general lighting in the form of an indirect lighting system and a low-luminance Wacolux 801 (Waldmann, Germany) desk luminaire (a special VDT workplace luminaire).

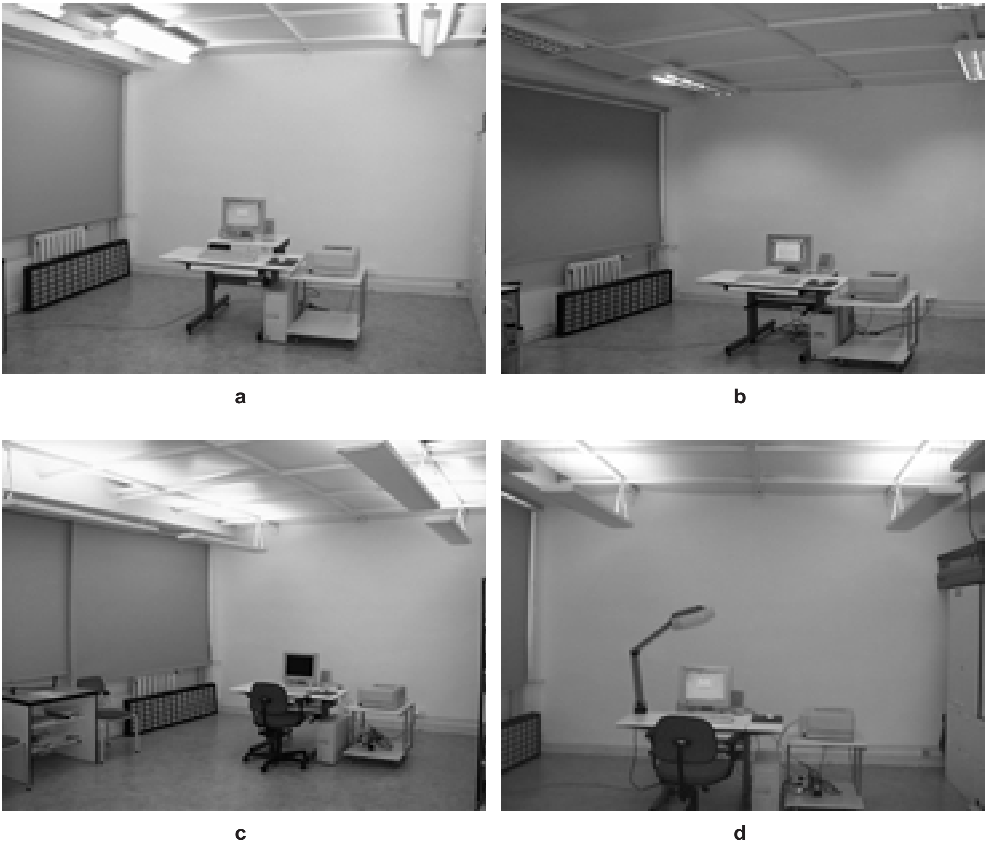

Figure 2. Luminous environment created by the following lighting systems: (a) direct-indirect, DI-L; (b) direct, D-L; (c) indirect, I-L; (d) compound, C-L.

All lighting systems were connected with a luminous flux control system, which allows easy adjustment of lighting parameters and no flicker effect was observed. The main assumption of modelling lighting conditions for each lighting system was to obtain the same illuminance level of about 500 lx on the work surface (a desk) and to avoid direct and reflection glare.

2.4. Visual Fatigue and Lighting Assessment

Visual fatigue was evaluated with a visual complaints questionnaire and additionally by simple measurements of two visual functions: the near point of accommodation (NPA) and the near point of convergence (NPC).

The subjective evaluation of visual complaints (asthenopic symptoms) was established with a questionnaire, which was filled in after each experimental session.

The NPA and NPC were measured with an RAF (Clement Clarke, UK) near point rule according to a measurement method described by London (1991a, b). Both parameters were measured before and after each experimental session. Changes in the calculated (mean) values of the NPA and the NPC before and after the experiment were measures of visual fatigue.

After each experimental session the participants had to fill in a questionnaire on different aspects of their perception of the luminous environment, on the influence of lighting on their well-being, and on the occurrence and intensity of asthenopic symptoms. Assessment was performed on a nominal scale and on an ordinal 5-point scale of the degree of strenuousness or intensity.

3. RESULTS

3.1. Visual Fatigue

Changes in the NPA and the NPC were obtained by subtracting "after" values from "before" values whereas changes in the accommodation amplitude (AA) by subtracting before values from after values for each participant.

TABLE 1. Changes of Accommodation and Convergence Under Different Lighting Systems

	Lighting System			
Parameter	**DI-L**	**D-L**	**I-L**	**C-L**
NPA (cm)				
M	0.99	0.71	0.70	0.34
SD	1.46	1.61	1.42	1.64
Variance	3.13	2.60	2.01	2.70
AA (Dptr)				
M	0.79	0.62	0.59	0.42
SD	1.34	1.34	1.36	1.08
Variance	1.81	1.79	1.84	1.16
NPC (cm)				
M	1.38	0.89	0.57	0.40
SD	1.69	1.53	1.65	1.49
Variance	2.84	2.33	2.73	2.20

Notes. DI-L—direct-indirect, D-L—direct, I-L—indirect, C-L compound, NPA—near point of accommodation, AA—accommodation amplitude, NPC—near point of convergence.

Those changes were statistically analysed. After the experimental session the NPA and the NPC moved away from the eyes, which corresponded with the reduction in accommodation and convergence abilities of the eyes. Table 1 presents the mean changes of accommodation and convergence after VDT work under different lighting systems.

Although the biggest reduction in accommodation was found for DI-L and the smallest for the C-L lighting system, those changes were not significant. According to ANOVA, convergence changes differ significantly in relation to the lighting system, $F(3) = 3.16$, $p = .03$. The biggest convergence reduction was found for the DI-L lighting system, which was significantly bigger than convergence changes for the I-L ($p = .02$) and C-L ($p = .005$) lighting systems.

Small and medium correlations were found between some visual fatigue symptoms and demographic data or changes in accommodation (Table 2). Accommodation and convergence changes not with gender, age, or VDT work experience. The convergence changes correlated with the type of lighting system but not with symptoms of visual strain. The bigger changes of accommodation after the experiment were accompanied by an increase of reported tired eyes.

The mean values of the intensity of complaints indicated that all asthenopic symptoms were assessed as small or medium regardless of the lighting system. The biggest intensities of discomfort were found for tired eyes, redness, blurring, sensitivity to light, burning, heaviness of eyelids, lacrimation, and itching. It was established (Wilcoxon signed ranks test) that sensitivity to light was significantly bigger for C-L than for D-L ($p = .02$), tiredness of eyes was significantly bigger for DI-L than for either I-L ($p = .05$) or C-L ($p = .04$), heaviness of eyelids was significantly bigger for C-L than for either D-L ($p = .05$) or DI-L ($p = .003$), and redness after the experiment was significantly bigger for both C-L ($p = .003$) and I-L ($p = .01$) than for the DI-L lighting system. The most frequently reported complaints were tired eyes, blurring, redness, burning, lacrimation, and sensitivity to light.

There were correlations between some visual complaints and gender or experience in VDT work (Table 2). Participants more experienced in VDT work seemed to report smaller sensitivity to light but bigger blurred vision than novices. On the other hand, women complained of stronger burning, sensitivity to light, blurred vision, and redness of eyes than men. No correlation between visual complaints and age was found.

TABLE 2. Spearman's Two-Tailed Correlations

	r (*p*)			
Feature or Symptom	**Accommodation**	**Convergence**	**Gender**	**VDT Work Experience**
Type of lighting system	*ns*	–.23 (.003)	*ns*	*ns*
Accommodation	—	.42 (<.001)	*ns*	*ns*
Tired eyes	.21 (.008)	*ns*	*ns*	*ns*
Sensitivity to light	.14 (.08)*	*ns*	.25 (.001)	–.16 (.04)
Burning	.13 (.08)*	*ns*	.17 (.03)	*ns*
Blurring	*ns*	*ns*	.20 (.01)	.18 (.02)
Redness before experiment	*ns*	*ns*	–.32 (<.001)	*ns*
Redness after experiment	*ns*	*ns*	–.35 (<.001)	*ns*

Notes. r—correlation coefficient, *p*—significance, *—close to significant level (tendency), *ns*—not significant, VDT—video display terminal.

3.2. Lighting Assessment

Most participants (about 68%) assessed the D-L system as comfortable for visual tasks and would have liked to work under that lighting system all the time. However the assessments of the considered lighting systems did not differ significantly.

The Friedman nonparametric test showed there was a significant influence of the type of lighting system on mood ($p = .011$) and on perceiving the room as too bright ($p = .004$). The participants' mood changed during the experimental sessions mostly in a positive direction under each lighting system. The room illuminated by the DI-L system was the one most frequently assessed as too bright, which 37% of participants perceived as strenuous (and a possible cause of discomfort glare).

Spearman correlation analysis between the subjective assessment of lighting features and age, gender, and experience in VDT work revealed that

- females more often than males found surfaces in the room excessively bright under the I-L system ($r = .54$, $p < .001$), which could be why they less often assessed that system as comfortable for visual work;
- females less often than males chose the D-L ($r = –.33$, $p = .03$) and I-L ($r = –.47$, $p = .001$) systems for regular work;
- professionals more often than novices chose the I-L ($r = .37$, $p = .013$) system for regular work;
- older participants less often than younger ones chose the DI-L ($r = –.47$, $p = .001$), D-L ($r = –.4$, $p = .007$), and I-L ($r = –.39$, $p = .009$) systems for regular work.

4. CONCLUSIONS

From the point of view of visual fatigue indirect and compound lighting systems are best. However, a compound lighting system should be used with special care for antiglare realization of task lighting.

The obtained results show that about 1.5 hrs of VDT work (with visual attention mainly on the screen) can cause small or medium asthenopic symptoms, regardless of the lighting system. The influence of the type of lighting system was established for sensitivity to light, heaviness of eyelids, tired eyes, and redness. The considerably bigger intensities of those complaints were found for compound and direct-indirect lighting systems. Therefore they should be used with special attention paid to their correct antiglare realization.

Generally users prefer a direct lighting system with dark-light luminaires but preferences for lighting systems with regard to users' features differ and lighting designers should be provided with some guidance. When most users in a given room are male indirect or direct (with dark-light luminaires) systems are preferred. Females and novices in VDT work are more sensitive to very bright surfaces in the room than males and professionals and they feel more comfortable when the luminances (mean values) of the wall and the work surface do not exceed 60 cd/m^2. Additionally novices, contrary to professionals, do not prefer an indirect lighting system. The compound system is recommended mainly for older users, who mostly prefer it.

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