Do Background Luminance Levels or Character Size Effect the Eye Blink Rate During Visual Display Unit (VDU) Work – Comparing Young Adults with Presbyopes?

Magne Helland, Gunnar Horgen, Tor Martin Kvikstad, and Arne Aarås

Buskerud University College, Department of Optometry and Visual Science
Box 235, N 3603 Kongsberg, Norway
magne.helland@hibu.no

Abstract. Eye blink rate for 19 healthy young adult volunteers (non-presbyopic) (15 females, 4 males; mean age 21.1, SD 5.9 years, range 19 to 29 years) were measured while working at an optimised VDU work station with two different character sizes (8 and 12 points Times New Roman). Two background luminance levels (approx. 100 cd/m^2 and 6000 cd/m^2) were used as glare sources. A marked reduction in eye blink rate from approx. 24 blinks per minute during easy conversation in between VDU work sessions to approx. 5 blinks per minute during active visually demanding VDU work was found. The results were compared with the results from a previoues similar study on 16 healthy presbyopic volunteers (8 females, 8 males; mean age 57.1 SD 7.2 years, range 46 to 67 years) [1]. For both groups a marked reduction in eye blink rate was found for VDU work compared with a rest situation. This was true whether the character size on the screen was "normal" (12 points) or fairly small (8 points), or whether the work was done under good and recommended visual conditions, or under a glare situation.

Keywords: VDU-work, eye blink rate, luminance levels, character size.

1 Introduction

The objective of this study was to determine if glare from the surroundings of a VDU and the size of the charcters used on the screen influenced the users eye blink rate. In a former study it was shown that in a group of presbyopic workers (mean age 57.1 years), an introduction of a moderate glare source in the surroundings of the VDU screen and the use of small characters (8 points), did not have a great influence on the eye blink rate whilw performing VDU work [1]. However, studies have shown that lighting conditions and optometric corrections are important factors in reducing visual discomfort [2]. The effect of optometric corrections on visual discomfort and musculoskeletal pain in VDU workers is also documented by

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Horgen and Aarås [3]. Glare has significant correlations to eye focusing problems and tired eyes [4]. The recommendations in Norway are that the ratio of luminance contrast distribution in the work area, near surroundings and periphery, should not exceed 1:3:10, and that maximum luminance contrast in the visible field should not exceed 1:20 [5]. In a laboratory study by Sheedy and Bailey [6], glare from a luminarie in the upper visual field was examined. Subjective rating of light discomfort was strongly related to the luminance level of the glare source. Further, the glare magnitude was significantly related to asthenopic symptoms ($p=0.004$) and musculoskeletal symptoms ($p=0.017$). In field studies, and during interviews of VDU-workers at their own workplace, the authors of this paper very often see a worktable and computer placement where the screen either is placed in front of the window, or in the corner of the office with a window close to the screen. This may increase the risk of glare problems. We also frequently experiece that VDU-workers, in particuler if young of age, select a combination of screen resolution and character size resulting in very small details on the computer screen. This seems to be driven by a desire of including as much information as possible at the screen at any given moment, in stead of having easily legible text and numbers. However, the latter situation may require more switching between different screens/programs.

2 Aims of the Study

The purpose of this study was to determine how glare from the near surroundings of a VDU, and reduced character size on the screen, influence the operators eye blink rate among optimally visually corrected young VDU-users. Further, to compare the results for young non-presbyopic VDU-users with the results from a group of optimally visually corrected presbyopes evaluated in a former study. For this group all demonstrated a marked drop in the eye blink rate for all test situations [1].

3 Design of the Study

The lowest luminance level of the surroundings of the screen (70 to 100 cd/m^2), and the normal size of the characters on the screen, (12 points New Roman), were defined as baseline. This baseline was recorded for each participant at the start and the end of the trial. The mean of these two measurements was used as a baseline in the statistical analysis [3]. The combination of high luminance/normal character size, high luminance/small character size and low luminance/small character size was tested according to a 3×3 orthogonal Latin square design [7]. Independent variables were the different luminance levels and the different sizes of the characters on the screen; the dependent variable was eye blink rate.

4 Materials and Methods

4.1 Subject Population

The young group consisted of 19 healthy student volunteers recruited from Buskerud University College (15 females, 4 males; mean age 21.1, SD 5.9 years, range 19 to 29 years). The eye blink rate for the non-presbyopic group were compared with the results from the presbyopic group from the previous study of 16 healthy presbyopic volunteers (8 females, 8 males; mean age 57.1 SD 7.2 years, range 46 to 67 years) [1]. All subjects gave informed consent to a protocol approved by Buskerud University College, and were free to withdraw from the study at any time, giving no reason. All subjects were experienced VDU-users, using computers daily as part of their work.

Inclusion Criteria. All subjects had a minimum distant and near best corrected binocular visual acuity of 1.0 (6/6 or 20/20) and normal eye status at the optometric examination.

Exclusion Criteria. Spectacle correction stronger than ± 6.00 DS (spherical equivalent), having active eye disease, or systemic disease with eye complications. Subjects with known anterior eye segment diseases like conjunctivitis, Sjögren's Sydrome, blepharitis etc., and subjects who had any evidence of tear film abnormalities were also excluded. Furthermore, subjects taking drugs that might influence either eye functions or muscle functions were also excluded.

4.2 Illuminance and Luminance

Two "glare" luminaries made up of an translucent acrylic diffusing fronts of 1.25 m × 0.57 m, equipped each with six 60 W fluorescent tubes, were placed behind and a little to the side of the computer screen. This was to simulate a VDU-screen placement in an office, with a window behind or near the screen. The intensity of the luminance was higher for the young non-presbyopes than for the presbyopic group, because very little effect was seen from the 2000 cd/m^2 used in the previous study [1]. In this study 5500 – 6000 cd/m^2 (measured across the screen) was used because such values are closer to natural luminance levels from a window on a sunny day. The illumination level was approx. 300 lx on the work table. The lowest luminance level of the surroundings of the screen was between 70 and 100 cd/m^2. These levels occur most frequently for VDU-workers when the gaze direction is parallel to the window wall. The light measurements were done by a Hagner Universal Photometer – type S3.

4.3 The Workplace

The experiment was conducted at an optimised VDU workplace with forearm support on the tabletop [8, 9]. The seat height, table height and monitor/eye distance were all positioned in accordance with anthropometrical dimensions of the subject. The line of sight to the midpoint of the computer screen was adjusted to approximately 15° below horizontal. A constant visual distance from the eyes to the midpoint of the screen was set to approximately 60 cm [10-12]. Two large "glare" luminaries were mounted vertically on the right side of the VDU, at approximately 45° horizontal angle from the sightline to the centre of the screen, simulating windows as they very often appear in a normal work station set up. All measurements took place in a 6.6 × 6.5 meters research laboratory with an air exchange of about 3.5 changes/h, but without any perceivable airflow (drafts). The temperature (mean 23º C) and relative air humidity (RH) levels (mean 36 %) were measured every 5 minutes during all registration sessions with a data logger (TinytagPlus). For any subject the range of temperature and humidity did not exceed more than ± 1° C and ± 2 % RH. The test set up is shown in figure 1.

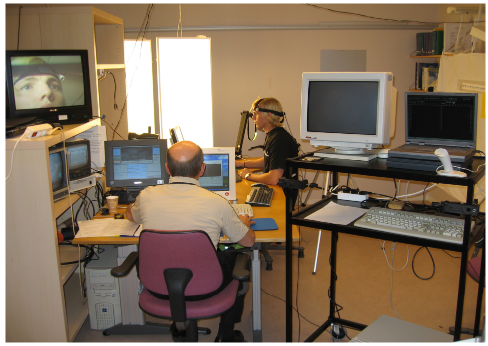

Fig. 1. The test set up, with workplace, glare source, and test person (to the right)

4.4 The Work Task

The work task was interactive work on the VDU screen. The VDU screen was a 15 inch LCD screen, with 1024 × 768 pixels resolution. Both the non-presbyopic and the presbyopic groups were investigated in relation to the use of two different character sizes (8 and 12 points Times New Roman), and two luminance levels (approx. 100 cd/m^2 and 6000 cd/m^2 for the young group, and approx. 100 cd/m^2 and 2000 cd/m^2 for the presbyopes) while working at an optimised VDU work station. The 12 points characters (capital letters 3 mm and small letters 2.2 mm in height) subtends a visual angle of approximately 16 minutes of arc for the capital letters, app. 12 minutes of arc for the small letters, when viewed at 62 cm distance. This represents a visual acuity demand of approximately 3 minutes of arc (2.5 for small letters), or 0.3 (6/18 or 20/60). This size is recommended for ordinary reading tasks, for subjects with visual acuity of 6/6 (20/20) or better. The 8 points characters (capital letters 2.4 mm and small letters 1.7 mm in height) subtend approximately 13 minutes of arc (capitals), and 9 minutes of arc (small letters) at 62 cm viewing distance. This represents a visual acuity demand of approximately 0.5 (6/12 or 20/40). This letter size is smaller than recommended for ordinary reading tasks. To support the selection of letter size, an interactive questionnaire were displayed at the website of the Norwegian Optometric Association. All visitors on the website were requested to measure the actual size of a capital letter as seen on their screen. They were recommended to use an ordinary ruler and estimate to the nearest tenth of a millimetre. This approach gives a realistic measure for the actual letter size seen on a VDU user's screen, since it is independent of screen resolution and image magnification. A total of 169 people responded. The results indicated that some VDU users select a screen/text setup resulting in letter size down to approximately 1 millimetre. However, most responders had a preference giving capital letters around 3 millimetres of height. The work task was to read an English scientific text, not familiar to the participants, shown on the screen. All e's in the text should be marked and bolded using the computer mouse only. The higher luminance from the large surface luminaries may in this way affect the eye blink rate.

4.5 Measurement of Eye Blink Rate

To record and investigate the eye blink rate a digital video camera (Sony DCRTRV22) (figure 2) and a video editing program (Pinnacle Studio DV8) were used. An eye blink was defined as any major movement of the lids where the upper and lower lids actually touched each other, or a significant movement of the upper lid to partly or fully cower the pupil area. For each subject five consecutive 10 minutes sessions were recorded including rest periods of approx. 5 minutes in between each active task session. All videotapes were later analysed by visual inspection while counting eye blinks using a mechanical counter. The counted number of eye blinks during each session was then converted to eyeblinks/min. Eye blinks were also counted during 3 to 5 minutes for the first break period in between session one and session two. The total number of eye blinks was then converted to eyeblinks/min. For most patients almost 100 % of the blinks were complete blinks. For this reason both complete and incomplete blinks were grouped together to give the blink rate per minute.

Fig. 2. The video camera used to record eye blinking is seen below and to the left of the VDU-screen

4.6 Test Duration

There were five test sections. Each section lasted 10 minutes of active recording, with a period of rest in between. The reason for 10 minutes active recording for each session is the recommendations by Mathiassen, who observed marginal information beyond approximately 10 minutes sampling of EMG of stereotyped work [13]. EMG measurements were done on the same subjects in parallel study both for the presbyopes [14], and for the young adults. The rest period was about 5 minutes.

According to Zaman and Doughty eyeblink monitoring of at least 3 minutes is required when assessing the spontaneous eye blink frequency in man [15]. The initial calibration procedure before the test sequences lasted about 90 minutes.

4.7 Optometric Examination

All subjects underwent an optometric eye examination some time before the investigation. Details of the procedures and criteria for correction are discussed elsewhere [16].

4.8 Background Factors

All participants were interviewed before inclusion in the study. During this interview, background factors such as age, gender, and extent and type of VDU work, as well as inclusion and exclusion criteria were discussed. The whole test procedure was explained for the participants.

5 Statistical Analysis

The study was set up with a Latin square design. The independent variables were the two different luminance levels and the two sizes of the characters. The dependent variable was eye blink rate. Results are given as group means with standard deviation and with confidence intervals (C.I.) based on the t-distribution. Comparison of the two groups was done by non-parametric tests (Mann-Whitney tests).Comparison within a group was done by using the non-parametric Wilcoxon Signed Rank test. Differences are considered statistical significant with a p-value <0.05.

6 Results

Both young adults and presbyopes showed a marked and similar reduction in the eye blink rate during VDU work, compared with a rest situation. For the non-presbyopic young adults the mean blink rate was reduced from 23.9 (SD 11.1) eye blinks per minute during easy conversation to 4.4 (SD 3.3) blinks per minute during active visually demanding VDU work. For the presbyopes the average blink rate for rest periods was 24.7 (SD 13.3) eyeblinks per min and 5.0 (SD 4.9) blinks per min for visually demanding VDU work. The results are represented as group means with 95% C.I. in table 1 and figure 3.

No significant differences between the two groups were found. This was true whether the character size on the screen was “normal” or fairly small, and whether the work was done under good and recommended visual conditions, or with glare in the near surrounding of the screen.

Table 1. Mean spontaneous eye blink rate (blinks/minute) for all test situations (young/presbyopes)

	Baseline [a]	12 points With glare [b]	8 points Without glare [b]	8 points With glare [b]	"Rest" after first recording
Group Means	4.4/5.0	5.6/5.7	4.4/5.7	5.0/5.4	23.9/24.7
Standard Deviation	3.3/4.9	4.3/6.7	4.1/5.2	3.2/5.0	11.1/13.3

[a] Baseline - the test situation with 12 points characters without glare, run before and after the three test situations in the Latin square design, were defined as baseline.
[b] These three test situations were administered in a Latin square design.

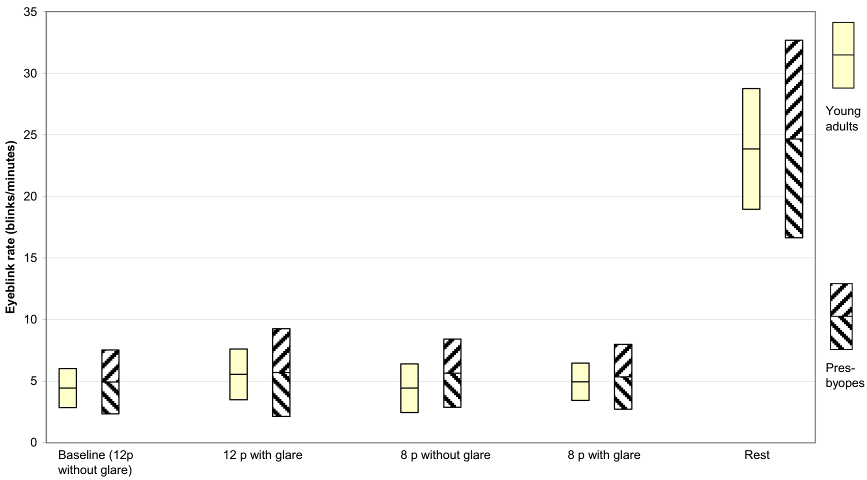

Fig. 3. Eye blink rate - results for both young adults and presbyopes as group means with 95% C.I.

7 Discussion

Normal and regular eye blinking is of uttermost importance to maintain the integrity of the ocular tear film, both to ensure optimal refractive properties of the anterior segment of the eye, and to prevent ocular discomfort. Blinking contributes to the maintenance of eye surface humidity, continuous rebuilding of the tear film structure into stable layers with unique protective and optical functions, and the drainage of the tears into the lacrimal drainage system. The human spontaneous eyeblink rate show considerable variability from 1.4 to 32.5 eyeblinks/min in different visual, mental and environmental conditions [17]. Typical blink frequencies at "rest" range from about 12 to 20 eyeblinks/min. In one study on 150 healthy volunteers the mean eyeblink rate at rest was 17 eyeblinks/min [18]. However, for the same group of subjects the eyeblink rate increased to 26 eyeblinks/min during conversation, and was as low as 4.5 while reading. The age of the subjects ranged from 5 to 87 years, but no age-related differences were found. In an other study on 41 grown up subjects the eyeblink rate during silence was 19.0 eyeblinks/min, while speech showed an increase to 24.7, and reading a decrease to 12.3 eyeblinks/min [19]. This is in line with our results showing that the average eyeblink rate for the “rest” period was approximately 25 blinks/min. Some major determinants of the blink rate at rest are extrinsic factors like dehydration, room temperature, relative humidity, and illumination. Both high temperature and high relative humidity reduce blink frequency [20]. In our study the room temperature varied less than 1° C, and the relative humidity less than 2 % RH for each individual participant.

High visual performance demands like VDU work is an important factor that reduces blink frequency. According to Acosta and co-workers [21] the reduced blink rate appears to depend on central neural mechanisms that are quite independent of peripheral sensory inputs. In their study the mean eyeblink rate at rest (12.4 eyeblinks/min) was reduced significantly by about 40% during performance of a VDU task [21]. Patel and co-workers [22] found a 5-fold drop in the eyeblink rate during VDU use. In their study the mean eyeblink rate before VDU use (18.4 eyeblinks/min.) was reduced to 3.6 during a card game play task at the computer. The results in our study were in line with the beforementioned studies. The average eyeblink rate was approximately 5 blinks/min for both young adults and presbyopes. Glare and the size of the characters did not influence significantly on the eyeblink rate. The tasks were performed with a distance of 60 cm and a gaze angle below horizontal to the midpoint of the screen of 15°. The distance was checked manually several times across the different sessions of the study. Further the study imitated the recommended position of the workers relative to the screen [23]. There was a great demand of precision when marking and bolding the e’s.

8 Conclusion

Neither small characters nor glare in the near surrounding of a VDU work station seems to have any significant influence on the eye blink rate. This applies both for non-presbyopic young adults and for presbyopes. However, visually demanding VDU work is associated with a very low eye blink rate. From our findings we conclude that highly visually demanding tasks at a VDU screen is an important factor reducing the eye blink rate.

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