Do the Luminance Levels of the Surroundings of Visual Display Units (VDU) and the Size of the Characters on the Screen Effect the Accommodation, the Muscle Load and Productivity During VDU Work?

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Abstract. This study aims at quantifying how much a background glare situation of a VDU, and different text sizes influence muscle load and production. Production was evaluated both as quantity of work, and number of errors that were made. The results showed no significant changes in the postural load in terms of electromyographic (EMG) measurements of m. trapezius and m. infraspinatus. However, a significant decrease in working speed and productivity was seen. There were no significant changes in the number of errors that was done. The transient myopic shifts (TMS) observed in an earlier study among presbyopic users [1] were not as clear in this study.

Keywords: VDU-work; Luminance; Muscle load; Myopia; Optometric corrections; Lighting.

1 Introduction

The objective of this study was to determine if glare from the surroundings of the visual display unit (VDU) influenced the users work productivity, state of refraction or muscle load. In a former study, we showed that in a group of presbyopic workers, an introduction of a moderate glare source in the surroundings of the VDU screen had an influence on productivity, but not on the postural load of the user [1]. 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 [3]. Glare has significant correlations to eye focusing problems and tired eyes [4]. High levels of background luminance have a negative effect on accommodation and increased visual fatigue [5]. The recommendations in Norway are that the ratio of luminance contrast distribution in the near, near surroundings and peripheral, should not exceed 1:3:10, and that maximum luminance contrast in the visible field of vision should not exceed 1:20 [6]. In a laboratory study [7], glare from a luminarie in the upper visual field was

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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 ($p=0.017$). The same researchers found that accumulated reading time was positively related to asthenopia ($p=0.0001$) and musculoskeletal symptoms ($p=0.0001$), indicating a fatigue effect. More detailed information of a correlation between visual discomfort and musculoskeletal pain is given by [8]. In a 6 years intervention study, a relationship between visual discomfort and pain in VDU workers was reported [2]. Average pain intensity in the neck and shoulder in previous month, previous six months, and the frequency of pain previous month and visual discomfort showed a relationship ($0.30< r <0.40$). A correlation was found between median trapezius load measured by electromyography (EMG) and average pain intensity and frequency in neck and shoulder and in visual discomfort. The correlation coefficient was between 0.25 and 0.30 ($p=0.03$) [2]. In another epidemiological study [9], a relationship was found between neck pain and visual discomfort, $r=0.40$, ($p=0.0003$).

2 Aims of the Study

Do the luminance levels of the surroundings of visual display units (VDU) and the size of the characters on the screen effect the accommodation, the muscle load and productivity during VDU work among young, non presbyopic workers? Are there differences in the above parameters when comparing with an earlier presbyopic study group? [10]

3 Design of the Study

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 x 3 orthogonal Latin square design [11].The lowest luminance level of the surroundings of the screen, was 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]), except for subjective refraction, where an initial measurement was taken before the subject was introduced to the work task, in order to see if a change in the focusing distance alone could lead to alteration in the visual system. Independent variables are the different luminance levels and the different sizes of the characters on the screen; the dependent variables are accommodation, muscle load and productivity. The study group consisted of young VDU workers (students).

4 Materials and Methods

4.1 Subject Population

Nineteen young, healthy volunteers (15 females and 4 males) were recruited from Buskerud University College. Age ranged from 19 - 29 years, with a mean of 22.1 years. 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, and using computers daily as part of their study 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. Furthermore, taking drugs that might influence either eye functions or muscle functions. Subjects suffering from physical handicaps to a degree that make it difficult to do electromyography (EMG) recordings and postural angles measurements.

4.2 Illuminance and Luminance

The illumination level was approximately 300 lx on the work table. The lowest luminance level of the surroundings of the screen was between 70 and100 cd/m^2. These levels occur most frequently for VDU-workers when the gaze direction is parallel to the window wall. The two “glare” luminaries each was equipped with six 60 W fluorescent tubes, with a diffusing screen of opal acrylic sheet. A variable rheostat made it possible to adjust the light emittance to different levels. The size of the diffusing screen was 1.25 m x 0.57 m, giving a luminance between 5500 – 6000 cd/m^2 (measured across the screen). This luminance is reached in an ordinary office environment when sunshine falls on thin, white curtains. 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 [12] . 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 15^0 below horizontal. A constant visual distance from the eye to the midpoint of the screen was set to approximately 60 cm [13]. The large “glare” luminaries were mounted vertically on the right side of the VDU, at approximately 45^0 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.

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 x 768 pixels resolution, The normal sized text (Times New Roman 12, 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 arch 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 small text size (Times New Roman 8, capital letters 2.4 mm and small letters 1.7 mm in height) subtend approximately 13 minutes of arch (capitals), and 9 minutes of arch (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. 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, looking directly on the screen all the time. The higher luminance from the large surface luminaries may in this way affect the visual parameters and muscle load. The whole test procedure was explained for the participants.

4.5 Refractive Measurements

Refractive power of the eyes was measured 6 times, before the experiment started, then between each test sequence and finally at the end to the Latin square period. The measurements were taken from both eyes without fixation of the head position, with a photo-refracting unit (PowerRefractor, Plusoptix AG). (More details about the PowerRefractor in [1])

4.6 Measurement of Load on the Musculoskeletal System

The postural load on the neck and shoulder muscles was quantified by EMG, using surface electrodes [14]. The load in m. trapezius (descending part) and m. infraspinatus was used as indicators of load on the neck and shoulder areas. The load on the m. trapezius muscle is selected because there are often complaints of pain and other symptoms from this area [12]. Furthermore, m. infraspinatus is chosen as an important stabilizer for the shoulder joint. Load on m. erector spina lumbalis was measured at L3 level. The Physiometer was used to measure the muscle load (figure 1). To perform continuous measurement of postural angels, three dual axis inclinometers are used. Angles were measured relative to the vertical by inclinometers attached to the upper arm, head and back.

The posture was controlled for by recording body movements. The static (0.1), median (0.5 and peak (0.9) values of the amplitude distribution function (ADF) were analysed. The EMG and the postural angle methods are described and the methodological limitations discussed by [15], [14].

4.7 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 (2002), who observed marginal information beyond approximately 10 minutes sampling of EMG of stereotyped work [16]. The rest period was about 5 minutes. The initial calibration procedure before the test sequences lasted about 90 minutes.

Fig. 1. Electrodes and angles sensor used by the Physiometer

4.8 Optometric Examination

All subjects underwent an optometric eye examination some time before the investigation. Details of the procedure and criteria for correction are discussed elsewhere [17].

4.9 Background Factors

All participants were interviewed before inclusion in the study. During this interview, background factors such as age, gender, and duration 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 are the two different luminance levels and the two sizes of the characters. The dependent variables are the accommodation power, load of the m. trapezius, m. infraspinatus and m. erector spina lumbalis muscles at L3 level. The postural angles were measured in order to control for body posture. A minimum of 16 subjects was needed in order to detect a difference in muscle load between 0.5 to 1 % maximum voluntary contraction (MVC) at a power level of 80 %. All results are given as group means with standard deviation using paired sample T-test, and repeated Wilcoxon Signed Ranks test. Pearson's Correlation Method was used for correlation statistics. Differences are considered statistical significant with a p-value = <0.05.

6 Results

6.1 Postural Load

In the young group, static m. trapezius activities did show small, but significant decrease when working with small characters without glare compared with baseline measurements. (p=0.05). When comparing m. infraspinatus from baseline to working with small print and glare, the static load also decreased (p=0.01).These changes are however small, and probably not of clinical significance. The differences of muscle activity within subjects between the different sessions were small. The maximal difference in static m. trapezius activity within subjects between the baseline and the measurements when the subjects were glared and worked with small characters was 1.0 % MVC.

6.2 Refractive Changes

Accommodative after-effects in terms of TMS during the test period were measured. There are only small changes in refraction over the test period, and only two of these reach near-significance level. There are, however, no significant changes within the Latin square period. The accommodative induced myopic shift takes place during the first test sequence. When checking for change from baseline to measurements within the Latin square period, only one reach near significance level (p=0,057). The changes are small, and probably not of clinical importance.

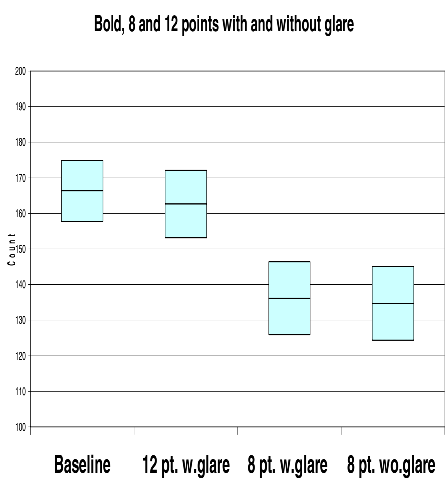

Fig. 2. Number of e's bolded per task unit

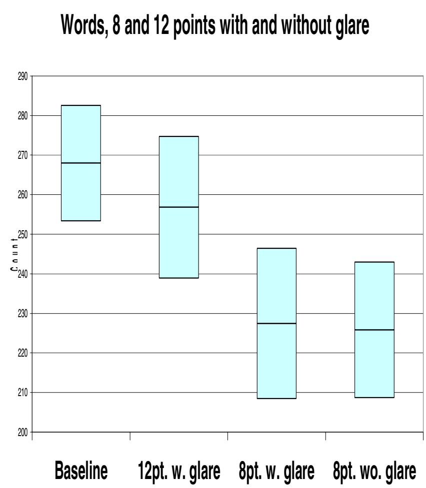

Fig. 3. Number of words processed per task unit

6.3 Productivity

Productivity in terms of the number of words processed over the testing period is shown in figure 2. The results demonstrates that the amount of work done is significantly reduced when working with the 8 points letters versus 12 points letters without glare (p=0.00).

The number of e's that were bolded went down significantly when introducing glare (p=0.01), and went even more down when going from large to smaller letters (p=0.00). (Fig. 3).

Errors are defined as not bolding an "e", or bolding another letter. There was no significant difference between the test situations when looking at the number of errors done per task unit.

7 Discussion

The illumination level was set as high as possible according the recommendations for traditional office work included computer work. The IES (1989) has recommended office lighting levels, depending of age profile of the workforce, between 500 and 1000 lx [18]. In order to get the most effective accommodation measurements, the highest illumination was limited to 300 lx. When taking the refractive measurements, the glare source had to be switched off. The level of luminance of the glare source was 6000 cd/m^2 measured across the screen.

The task was demanding, both visually and physically, because of the static work situation. The initial static muscle loads of m. trapezius and m. infraspinatus was 3,0 % MVC and 4,0% MVC respectively, as group mean values. These values did not change much during the test duration. Among a group of adults computer users tested, a much higher static infraspinatus load (13,1 %) was found, so these values are not in line with the former study [1]. Other studies indicate that high precision seems to increase muscle load [19]. They showed that musculus infraspinatus had a high precision-dependence during tracking work. The m. infraspinatus seems to be acting as a responder to precision demands in the shoulder region, which may be a consequence of its function as shoulder joint stabilizer. This is supported by high muscle activity in m. infraspinatus during cleaning. Søgaard reported more than 10 % EMG max for mopping activity [20].

In this study the participants supported their forearms on the table top. When supporting the forearms during work with the mouse, the m. trapezius load is reduced [21]. In a study by Palmerud et al (1995), they showed that by voluntary reducing the trapezius load, the load in infraspinatus muscle increased [22]. The static levels of m. infraspinatus activity showed great individual differences between the subjects with the highest values of approximately 20 % MVC. The reason may be that in order to obtain sufficient positional accuracy of the hand and arm, the shoulder girdle need to be stabilised by means of muscular activity. This is achieved by co-contraction of muscle spanning these joints [23]. In high precision movements, the noise effects in neuro-motor control are counteracted by means of increased co-contraction. The stiffness of co-contraction is expected to filter out noise effects. The level of co-contraction will be even higher under stressful tasks conditions due to increased neural noise [24] which may be the case in such testing situations. In this study precision demand was extensive. It has been shown that precision has an effect on m. trapezius load during an aiming task on computer by using mouse [25].

The accommodative induced TMS observed when working at the VDU-screen are small and not statistically significant. TMS is reported in earlier studies [26] [27]. However, in a 6 years follow up study of 692 VDU users no such effect was established. [28]. The age of this study population (mean age = 22,1 (19 – 29) years) is such that a TMS could be expected. However, in a former study the subjects had a mean age of 57 years (46 – 67) and it is interesting to observe that the myopic shift was higher in that presbyopic group [1]. One possible explanation could be that the TMS observed in the presbyopic group normalized slower than in the young group. In a group of non presbyopes, most of the TMS normalized within 2 minutes [29], and Rosenfield (1992) found that most of TMS disappeared in 20 – 50 s. post task [30]. Myopic shifts are thought to be one factor in myopia development [31], although in several studies no myopia development following VDU-work has been found [32] [33]. To follow this myopic shift over time was not within the scope of this project.

8 Conclusion

Working with small characters and/or glare did not impose clinically significant changes in muscle load in term of EMG values. M. infraspinatus was not so heavily loaded in the young group compared with the presbyopic group, who showed a relatively heavy infraspinatus loading during this type of computer work. A very small myopic shift were registered in the young group, a significantly higher myopic shift is seen in the older group, in spite of these test subjects being presbyopic. Productivity, in terms of less amount of text processed and an increased number of errors, went significantly down for both groups when working with small characters and glare. However, the young group scored higher both in the total amount of work done and the young group also made less errors per time unit. The results indicate that a recommendation to use font sizes of about 3 mm for 60 cm. working distance is appropriate. Further, background glare should be avoided.

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References

1. Horgen, G., et al.: Do the Luminance Levels of the Surroundings of Visual Display Units (VDU) and the Size of the Characters on the Screen Effect the Accommodation, the Fixation Pattern and the Muscle Load During VDU Work. In: Salvendy, G. (ed.)Human Computer International 2005, U.S. CD, Lawrence Erlbaum Associates Inc., New Jersey, 2005 . Human Computer International 2005, U.S. CD, vol. 1 (2005) ISBN: 0-8058-5807-5 [CD]

2. Aarås, A., et al.: Musculoskeletal, Visual and Psychosocial Stress in VDU Operators before and after Multidisciplinary Ergonomic Interventions. Applied Ergonomics 29(5), 335–354 (1998)
3. Horgen, G., Aarås, A.: Visual Discomfort Among VDU-Users wearing Single Vision Lenses compared to VDU-Progressive lenses. In: Human Computer International 2003. Crete: Lawrence Erlbaum Associates. Mahwah, New Jersey. (2003)
4. Hedge, A., Williams, R.S.J., Franklin, D.B.: Effects of lensed-indirect and parbolic lighting on the satsfaction, visual health, and productivity of office workers. Ergonomics 38(2), 260–280 (1995)
5. Wolska, A., Marcin, S.: Luminance of the Surroound and Visual Fattigue of VDT Operators. International Journal of Occupational Safety and Ergonomics 5(4), 553–580 (1999)
6. Bjørset, H.-H.: Lighting for visual display unit workplaces. in Work With Display Units. Stockholm: Elsevier Science Publications BV North Holland (1986)
7. Sheedy, J.E., Bailey, I.L.: Symptoms and Reading Performance with Peripheral Glare Sources. In: Work With Display Units 94. University of Milan: AES Congress S.r.l. Via Scheiwiller, 1–20 2013 Milano - Italy (1995)
8. Horgen, G., Aarås, A.: Optometric Examination and Correction of VDU-Workers. In: Advances in Occupational Ergonomics and Safety, IOS Press - Amsterdam, USA (1998)
9. Horgen, G., et al.: A Cross-Country Comparison of Short- and Long Term Effects of en Ergonomic Intervention on Musculoskeletal Discomfort, Eyestrain and Psychosocial Stress in VDT-Operators; Selected Aspects of the Internatational Project. International Journal of Occupational Safety and Ergonomics (JOSE) 11(1), 77–92 (2005)
10. Helland, M., et al.: Do the Luminance Levels of the Surroundings of Visual Display Units (VDU) and the Size of the Characters on the Screen Effect the eyeblink rate During VDU Work. In: 11. Conference on Human Computer Interaction, Las Vegas - USA: Lawrence Erlbaum Associates Inc., New Jersey (2005)
11. Jones, B., Kenward, M.: Design and Analysis of Cross-over Trials. Chapman & Hall, London (1990)
12. Aarås, A.: Acceptable Muscle Load on the Neck and Shoulder Regions Assessed in Relation to the Incidence of Musculoskeletal Sick Leave. International Journal of Human-Computer Interaction 2(1), 29–39 (1990)
13. Jaschinski-Kruza, W., Heyer, H., H, K.: Preferred position of visual displays relative to the eyes: a field study of visual stain and individual differences. Ergonomics 41(7), 1034–1049 (1998)
14. Aarås, A., et al.: Reproducibility and stability of normalized EMG measurements on musculus trapezius. Ergonomics 39(2), 221–226 (1996)
15. Jonsson, B.: Measurement and evaluation of local muscular strain in the shoulder during constrained work. Journal of Human Ergology 11, 73–88 (1982)
16. Mathiassen, S.E., Burdorf, A., van der Beek, A.J.: Statistical power and measurement allocation in ergonomic intervention studies assessing upper m.trapezius EMG amplitude. A case study of assembly work. Journal Electromyography Kinesiology 2002(12), 45–57 (2002)
17. Horgen, G., Aarås, A.: Optometric Examination and Correction of VDU Workers. In: The 1. international Conference on Applied Ergonomics. (ICAE'96) Istanbul, Turkey: Istanbul–West Lafayette Publishing USA (1996)
18. IES, VDT Lighting; Recommended practice for office lighting with Visual Display Units. In: ed. I. _RP. 1989, New York: Illumination Engineering Society of North America (1989)

19. Milerad, E.: Effects of presicion and force demands, grip diameter and arm support during manual work; an electromyographic study. Ergonomics 37(2), 255–264 (1994)
20. Søgaard, K.: Biomechanics and Motor Control during Repetetive Work. A biomedical and electromyographical study of floor cleaning., in Departement of Physiology. National Institute of Occupational Health & Human Physiology. University of Copenhagen - Denmark: Copenhagen (1994)
21. Aarås, A., Thoresen, M.: Work Posture and Musculoskeletal Pain. In: Advances in Applied Ergonomics. Istanbul - Turkey: USA Publishing - Istanbul - West Lafayette (1996)
22. Palmerud, G., Kadefors, R.: Voluntary redistribution of muscle activity in human shoulder muscles. Ergonomics 38(4), 806–815 (1995)
23. Akazawa , K., Milner, T.E., Stein, R.B.: Modulation of reflex EMG and stiffness in response to stretch of human finger muscle. Journal of Neurophysiology 49, 16–27 (1983)
24. Galen, G.P.V., Müller, M.L.M., Gemmert, A.W.: Forearm EMG response activity during motor performance in individuals prone to increased stress reactivity. American Journal of Industrial Medicine 41, 406–419 (2002)
25. Visser, B., et al.: Effects of precision demands and mental pressure on muscle activaion and hand forces in computer mouse tasks. Ergonomics 47(2), 202–217 (2004)
26. Mutti, D.O., Zadnik, K.: Is computer use a risk factor for myopia? Journal of the American Optometric Association 67(9), 521–530 (1996)
27. Ciuffreda, K.J., Ordonez, X.: Vision Therapy to Reduce Abnormal Nearwork Induced Transient Myopia. Optometry and Vision Science 75(5), 311–315 (1998)
28. Cole, B.L., Maddocks, J.: Effect of VDU's on the eyes: Report of a 6 year Epidemiological Study. Optometry and Visual Science 73(8), 512–528 (1996)
29. Jaschinski-Kruza, W.: Transient myopia after near visual work. Ergonomics 27(11), 1181–1189 (1984)
30. Rosenfield, M., Ciuffreda, K.J., Novogrodsky, L.: Contribution of accomodation and disparity-vergence related to transient nearwork-induced myopic shift. Ophthalmic and Physiological Optics 12, 433–436 (1992)
31. Kinge, B., et al.: The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. Acta Ophthalmologica Scandinavia 78(1), 26–29 (2000)
32. Cole, B.L.: Do video display units cause visual problems? - a bedside story about the processes of public health decision-making. Clinical and Experimental Optometry 86(4), 205–220 (2003)
33. Rechichi, C., Scullica, L.: Trends regarding myopia in video terminal operators. Acta. Ophthalmologica Scandinavia,1996 74, 493–496 (1996)