# An Examination of the Relationship between Visual Fatigue Symptoms with Flicker Value Variations in Video Display Terminal Users

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## ABSTRACT

In most sensitive occupations such as nuclear, military and chemical industries closed circuit systems and visual display terminals (VDTs) are used to carefully control and assess sensitive processes. Visual fatigue is one of the factors decreasing accuracy and concentration in operators causing faulty perception. This study aimed to find out a relationship between visual fatigue symptoms (VFS) of Flicker value variations in video display terminal (VDT) operators.

This cross-sectional study, conducted in 2011, aimed to examine visual fatigue and determine the relationship between its symptoms and visual flicker value changes in 248 operators of VDTs in several occupations. The materials used in this study were a visual fatigue questionnaire of VDTs and a VFM-90.1 device. Visual fatigue was measured in two stages (prior to beginning to work and 60 min later). The data were analyzed by SPSS11.5, using descriptive statistics, paired t-test, simple and multiple linear regressions, correlation and recognition coefficients. Then regression equations of changes in flicker value depending on the changes in the main domains and the changes in final score before the questionnaire were obtained.

Paired t-test indicated significant differences in the mean score of visual fatigue symptoms and the mean score of flicker value between the two stages, respectively ($P \leq 0.001$). Simple and multiple regressions of flicker value variations, for the last visual fatigue changes in questionnaire score and the four main domains of the questionnaire were obtained R2 = 0.851 and R2 = 0.853, respectively. Correlation coefficient in the above tests indicated reverse and significant relationships among flicker value changes with changes in questionnaire score and visual fatigue symptoms.

Diagnosing the first symptoms of visual fatigue could be an appropriate warning for VDTs operators in sensitive occupations to react suitably, in behavior and management, to control or treat visual fatigue and prevent errors efficiently.

**Key words**: Visual Fatigue, Flicker Value, VDT Operators

## INTRODUCTION

Today's, human life faces the technological revolution in different aspects. As technology grows rapidly, its related tools such as a monitor of computer and VDTs grow as well [1]. At the advent of computers and monitors, scientists were concerned with their radiations but gradually eye complaints were reported to be the main concern [2]. Different studies have revealed that 75% of computer users have experienced occupational eye problems [3-4]. Besides, destructive effects made by VDTs are closely related to eye impairments and could be effective in staff's accuracy [5].

Visual fatigue includes symptoms such as headache, alienation from work and eye pain [6]. The commonest complaints reported in different studies done on VDT users include pain and pressure in the eye, dry eye, tearing, irritation and redness, blurred vision and double vision [5, 7]. Often, visual fatigue symptoms and computer vision syndrome largely overlap [8]. In a study carried out in 2007 to assess the visual fatigue of telecommunication operators, the results revealed that there was a close and significant relationship between neck-shoulder pain and eye complaints [9]. In a parallel study done in 2007-2008 in Yazd Medical University on 105 people, results showed that eye complaints among computer users include visual fatigue (79%), eye burning (57.7%), tearing (33.4%) and eye redness (30%). Besides, the mentioned complaining revealed a significant relationship with improper working conditions [10]. In a study to assess computer user's visual function, the results showed that studying e-books lead to higher eye complaints than studying books. Moreover, visual function with studying books is significantly better than studying e- books [11]. Providing and promoting devices assessing visual fatigue shows an increasing trend. One of such devices is visual fatigue questionnaire [12-15]. The other device assessing variations of visual fatigue objectively is VFM-90.1 designed based on Flicker Value variations. Flicker Value is based on the critical fusion frequency (CCF) [16-17]. Flicker value index measures the eye's retina's accuracy and function which has a high sensitivity and easy application [12]. Visual performance and personnel's accuracy show a reverse relationship with their visual fatigue [11]. Thus, with diagnosing the major visual fatigue symptoms and determining the correlation of each of the main domains of visual fatigue and its symptoms with flicker value variations (as a physiological index), it is possible to act properly in providing proper strategies to prevent and control VDT user's visual fatigue. As a consequence human errors and related accidents will be prevented. This study aimed to find out a relationship between visual fatigue symptoms (VFS) of Flicker value variations in video display terminal (VDT) operators.

## MATERIALS AND METHODS

This study is of cross-sectional type and was done in 2011 on professional VDT users (such as bank clerks, typists, secretariats, office workers, telephone operators and students). The sample size was 252 (using a confidence interval of 95% (1.96), test power of 80% (0.84), the estimated standard deviation 1.7 and sampling error 0.3). Sampling was performed by convenience of haphazard among the VDT users. To assess visual fatigue and its symptoms, visual fatigue questionnaire was used [1]. Simultaneously, the background and demographic data of participants were gleaned using the checklist. Also, to assess Flicker value variation, CCF index and laboratory devices assessing visual fatigue variations (Iranian VFM-90.1) were used.

The questionnaire consisted of 15 questions in four main domains of eye strain, visual impairments, and surface eye impairment and out of eye impairments. Its reliability was reported 0.75. Visual fatigues in the questionnaire were mentioned qualitatively and quantitatively. The maximum score of the questionnaire is 10 including No fatigue (≤0.65≤), Low fatigue (0.66-2.36), Moderate fatigue (2.37-3.88) and severe fatigue (≥3.89≥) (1). Visual fatigue changes CFF index [1, 17]. Visual fatigue variation was assessed based on CFF variation in two steps (before and after working of 60 min). Before the test, the study's qualifications including uncorrected reflected errors, cold and alcohol were checked. The mentioned cases were done e-chart and expert nurse, if the participants' eyes strengths were lower than 10/10 or they were being under treatment, would not be entered into the test. They declared their lack of taking any medications or alcohol. Also before the test, participants were trained how to answer the questionnaire and to flicker value variations. They were required not to work with the monitor, watch television or study 15 min before the test. Then the primary flicker value was tested and recorded using the VFM90.1, at the same time the questions were asked of the participants by the researcher and recorded. Then the participants returned to their work. The second step was repeated just like the first step in minimal 60 minutes. In the meantime, no participant was allowed to drink or eat anything during the intervals. The interval time and rest time before the test was based on pilot study done on 40 people before the main study. In the second step, the user's flicker value was assessed immediately after work and the questionnaire was completed simultaneously. Data analysis was done using SPSS 11.5 and descriptive statistics, paired T-test, simple and multivariate linear regression. Visual fatigue and the correlation of each symptom and the main domains of the questionnaire were assessed by the use of the flicker value variations based on Hertz. The regression was recorded if significant. The questionnaire data and flicker value variations were done by occupational health experts. To determine the relationship between visual fatigue symptoms variations and flicker value variations, linear regression test was carried out for all visual fatigue symptoms and the flicker value variations, correlation coefficient (R), recognition coefficient (R2) and their significant levels were obtained.

## RESULTS

After investigating the first checklists, questionnaires and having gathered the data, 4 of the participants were recognized disqualified and therefore withdrawn from the study leading to a reduction of the whole participants to 248. 24.6% of the participants were male and 75.4% female. The participants' average age proved to be 35.73 ± 6.6. Besides, the participants' eye distance to monitor showed to be 54.84 ± 11.9 centimeters. 63.3% and 36.7% of the monitors used in this study were LCD and CRT, respectively. Based on the second results of this study, the most complaints of the participants were reported to be at Table 1.

The averages of the flicker value in first and second steps were 38.46 ± 2.00 and 37.23 ± 1.93 Hertz, respectively. Also, the average variation of the flicker value in two steps was 1.23 ± 0.99 Hz. Paired t-test proved that the average of flicker value variations studied in the two times of investigation showed a significant difference (p-value ≤0.001). Visual fatigue questionnaire (for Video Display Terminal Operators) can estimate the visual fatigue both qualitatively and quantitatively. The average of the participants' visual fatigue score in two steps was 0.41 ± 0.53 and 1.89 ± 1.47. Besides, the average of the variation in two steps was 1.48 ± 1.27 (the second step was done 60 min after work). Paired t-test showed a significant difference for all variation scores of visual fatigue symptoms (15 questions) in both steps (p. value ≤0.001). Based on the assessment method of the questionnaire's final score, visual fatigue frequency was obtained (Table 2).

In order to determine the outlier out of 3 standard deviations of the regression lines, the primary regression was carried out for all the items. Some samples were omitted based on SPSS report and the results of stepwise linear regression (Table 3).

**Table 1:** The most complaints of VDT users

| Complaints | Value (%) |
|---|---|
| **Heavy eyelids** | 77.8 |
| **Sting eyes** | 70.6 |
| **Eye massage need** | 63.3 |
| **Around eye pressure** | 61.7 |
| **Headache** | 56.5 |
| **Eye pain** | 46 |
| **Watery eyes** | 43.5 |
| **Obscurity and haziness** | 32.3 |
| **Vertigo** | 31 |
| **Word or line skipping during reading** | 30.6 |
| **Dried eye sensation** | 25 |
| **Near vision difficulty** | 24 |
| **Far vision difficulty** | 23.4 |
| **Double vision** | 24 |

**Table 2:** Frequency disruption of visual fatigue in VDT users based on the questionnaire assessment levels

| Zone of visual fatigue | First step | | Second step | | Lower bound | Upper bound |
|---|---|---|---|---|---|---|
| | Frequency | Percent | Frequency | Percent | | |
| **No fatigue** | 199 | 80.24 | 46 | 18.5 | 0 | 0.65 |
| **Low fatigue** | 45 | 18.14 | 132 | 53.2 | 0.66 | 2.36 |
| **Moderate fatigue** | 4 | 0.016 | 41 | 16.5 | 2.37 | 3.88 |
| **Sever fatigue** | 0 | 0 | 29 | 11.6 | 3.89 | 10 |

**Table 3:** The specifications of linear regression equations of flicker value variations based on the variation of visual fatigue symptom score

| Independent variable | | Number of valid sample (for regression) | Correlation coefficient (R) | recognition coefficient ($R^2$) | *p*.value |
|---|---|---|---|---|---|
| **Dry eye sensation ($X_1$)** | | 243 | -0.48 | 0.230 | ≤ 0.001 |
| **around eye pressure ($X_2$)** | | 246 | -0.68 | 0.415 | ≤ 0.001 |
| **Sting eyes ($X_3$)** | | 248 | -0.60 | 0.368 | ≤ 0.001 |
| **Heavy eyelids ($X_4$)** | | 248 | -0.63 | 0.401 | ≤ 0.001 |
| **Watery eyes ($X_5$)** | | 245 | -0.62 | 0.391 | ≤ 0.001 |
| **Vertigo when looking at the monitor ($X_6$)** | | 245 | -0.59 | 0.350 | ≤ 0.001 |
| **Obscurity and haziness($X_7$)** | | 243 | -0.56 | 0.319 | ≤ 0.001 |
| **Double vision ($X_8$)** | | 240 | -0.56 | 0.315 | ≤ 0.001 |
| **Headache during working ($X_9$)** | | 247 | -0.61 | 0.376 | ≤ 0.001 |
| **Sleepiness ($X_{10}$)** | | 245 | -0.57 | 0.330 | ≤ 0.001 |
| **Eye pain ($X_{11}$)** | | 246 | -0.68 | 0.467 | ≤ 0.001 |
| **Near vision difficulty ($X_{12}$)** | | 246 | -0.49 | 0.243 | ≤ 0.001 |
| **Far vision difficulty ($X_{13}$)** | | 247 | -0.52 | 0.275 | ≤ 0.001 |
| **eye massage need ($X_{14}$)** | | 246 | -0.54 | 0.298 | ≤ 0.001 |
| **Word or line skipping during reading ($X_{15}$)** | | 245 | -0.74 | 0.548 | ≤ 0.001 |
| **Main domains of questionnaire** | **eye strain ($X_{16}$)** | 244 | -0.84 | 0.715 | |
| | **visual impairments($X_{17}$)** | 244 | -0.70 | 0.498 | ≤ 0.001 |
| | **out of eye impairments ($X_{18}$)** | 246 | -0.77 | 0.592 | ≤ 0.001 |
| | **surface eye impairment ($X_{19}$)** | 246 | -0.74 | 0.556 | ≤ 0.001 |
| **Final Score changes of questionnaire after 2 step ($X_{20}$)** | | 241 | -0.92 | 0.851 | ≤ 0.001 |

Multiple –linear regression test was used to calculate the flicker value variations based on the score variations of the main domains of the questionnaire. Having carried the primary regression, its equation was determined; (relation 1).The number of outlier of 3 standard deviations was 7. Its recognition coefficient (R2) was proved to 0.853. Moreover, the equation of flicker value variation based on the questionnaire's final score variations was obtained, (relation 2).

**Relation 1:** The equation of multiple linear regression based on score variations of the main domains of the visual fatigue questionnaire:

$$\Delta CFF = -[0.162 (X_{19}) + 0.181 (X_{18}) + 0.174 (X_{17}) + 0.221 (X_{16}) + 0.143]$$

**Relation 2:** The equation of the simple linear regression based on the questionnaire's final score variations:

$$\Delta CFF = - [0.754 (X_{20}) + 0.149]$$

**Table 4:** Accepted models summaries (relation 1 and 2)

| | Independent variable | Variable coefficient | p.value | recognition coefficient ($R^2$) | Correlation Coefficient (R) | Number of Valid Sample |
|---|---|---|---|---|---|---|
| Equation 1 | Eye strain ($X_{16}$) | -0.221 | < 0.001 | 0.853 | -0.924 | 241 |
| | Visual impairments($X_{17}$) | -0.174 | < 0.001 | | | |
| | Out of eye impairments ($X_{18}$) | -0.181 | < 0.001 | | | |
| | Surface eye impairment ($X_{19}$) | -0.162 | < 0.001 | | | |
| Equation 2 | Questionnaire's Final Score variation after two steps ($X_{20}$) | -0.754 | < 0.001 | 0.851 | -0.923 | 241 |

## DISCUSSION

Based on the results of this study in hand the most frequent visual fatigue symptoms were about eye strain (around eye pressure, eye massage need and heavy eyelids), out of eye impairments (headache and sleepiness) and surface eye impairment (sting eyes), respectively. The frequency of other symptoms of visual fatigue and main domains of visual impairments showed to be less than 50%. The study of Biswass *et al.* led to prove that eye dry amount of computer users was 68.5% and 47.7% in the control group [18]. In a study carried out on computer users of Yazd University of Medical Sciences, eye complaints frequency was declared to be as follows; visual fatigue 79%, sting eye 57.7%, watery eyes 33.4% and eye redness 30%.[10]. Besides, Dehghani *et al.* carried out a study on a group of bank clerks working with computer aiming to perform their organizational duties (as the case group) and a group of bank clerks not dealing with computer (as the control group), eye strain and fatigue symptoms in case and control groups were as follows; eye burn and tearing 79% vs. 45%, eye dryness 66% vs. 32% and visual fatigue while working 64% vs. 40%. In the study results, it was mentioned that such complaints as sting eyes, watery eyes, dryness and visual fatigue feeling were remarkably higher in computer users than in the control group [2]. This study's results showed that the last test of visual fatigue symptoms of VDT users, belong to the main domain of visual impairments, that happens to be the major reason of human errors. Other vast symptoms of the highest frequency could be considered as pre-warning, the primary warning of creating and promoting visual fatigue for the VDT users. The users will be informed of their downward losing accuracy and efficiency during time to take consideration in removing or controlling visual fatigue. Besides, paired t-test results show that the average scores of visual fatigue questions bear a significant difference in pre- and post-tests. Such results indicate that the minimum amount of 60 min working with VDT to make any changes in visual fatigue and developing its symptoms in VDT users was accurately determined. All the symptoms have shown significant difference. Whereas, in a parallel study done in 2007 on three popular monitors in china to evaluate visual ergonomics (degree of visual fatigue, vision function and mental satisfaction), the minimum amount of text studies by monitors was 100 min. In this study in hand the relationship among main domains and the symptoms of visual fatigue regarding flicker value variations (ΔCFF) was investigated. To meet such an aim, just like the studies done, visual fatigue was evaluated simultaneously with questionnaire and CCF changes [13, 19]. What distinguishes this study regarding the parallel ones of the type is its investigating the relationship of visual fatigue (mental symptoms) with CFF (physiologic criterion). CCF index is an objective physiologic quality that is answered similarly in all human societies [1]. Regression test results indicated that the highest amount of R2 is of the questionnaire's final score variations in both steps; such a result indicates that all the symptoms and questions proved to be effective directly or indirectly in the final evaluation of visual fatigue. Regarding R2, approximately 85% of flicker value variations of VDT users could be estimated by questionnaires score changes. On the other hand, there is a strong and significant correlation between CFF changes (physiological index) and questionnaire score variations as a mental index. The more CFF changes and decreases of threshold frequency, the more visual fatigue is witnessed.

Among the main domains of the questionnaire, the best and the most suitable domain to estimate the individual's flicker value belongs to the main domain of eye strain (R2 = 0.71). Among the questions and the symptoms of the visual fatigue, the highest amount of recognition coefficient belongs to eye massage need (R2 = 0.54), eye pain (R2 = 0.46), around eye pressure (R2 = 0.41), heavy eyelids (R2 = 0.40). All the four mentioned symptoms are the sub-domains of the eye strain. Besides, it could be claimed that controlling the effective factors on the eye strain, VDT users' visual fatigue could also be controlled, significantly. It could also be mentioned that, the first symptoms of VDT users' visual fatigue belong to the main domain of eye strain.

Multiple-linear regression test was used to determine the regression equation and also to connect the main domain variation of questionnaire and flicker value changes. The equation's recognition coefficient (relation 1) was 0.853, which proved to be equivalent to a recognition coefficient simple linear regression equation of the questionnaire's final score variations (table3). It indicated that the main domain of the questionnaire has a strong correlation with flicker value variations. Besides, based on table 2, the least amount of recognition coefficient and correlation of flicker value variations with visual fatigue symptoms belong to dry eye sensation ($R2 = 0.23$) and near vision difficulty ($R2 = 0.24$). Having been limited and due to the inaccessibility of the individual's jobs and equipment left us unable to investigate all the effective factors on operator's visual fatigue. Unless such studies are done in laboratory conditions, better and more efficient scientific results would not be achieved.

## CONCLISION

The most significant symptoms of visual fatigue are of eye strain domain and the least developing symptoms belong to visual impairments domain. On the other hand, all the symptoms of visual fatigue of VDT users and its domains displayed a linear and vice versa relationship with VDT users' flicker value variations. Determining the most important and the first symptoms of visual fatigue symptoms as well as those of delayed symptoms of VDT users' visual fatigue could be a decent warning for the trained and professional users. Presenting a suitable behavioral and management reaction to controlling or removing the visual fatigue will lead to effective prediction and prevention of those human errors related to the visual fatigue problems.

## COMPETING INTERESTS

Authors declare that there is not any competing interest.

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