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Designing and Validation a Visual Fatigue Questionnaire for Video Display Terminals Operators

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Original Article

ABSTRACT

Background: Along with the rapid growth of technology its related tools such as computer, monitors and video display terminals (VDTs) grow as well. Based on the studies, the most common complaint reported is of the VDT users.

Methods: This study attempts to design a proper tool to assess the visual fatigue of the VDT users. First draft of the questionnaire was prepared after a thorough study on the books, papers and similar questionnaires. The validity and reliability of the questionnaire was confirmed using the content validity index (CVI) beside that of the Cronbach's Coefficient Alpha. Then, a cross-sectional study was carried out on 248 of the VDT users in different professions. A theoretical model with four categories of symptoms of visual fatigue was derived from the previous studies and questionnaires. Having used the $AMOS_{16}$ software, the construct validity of the questionnaire was evaluated using the confirmatory factor analysis. The correlation co-efficiency of the internal domains was calculated using the SPSS 11.5 software. To assess the quality check index and determining the visual fatigue levels, visual fatigue of the VDT users was measured by the questionnaire and visual fatigue meter (VFM) device. Cut-off points were identified by receiver operating characteristic curves.

Results: CVI and reliability co-efficiency were both equal to 0.75. Model fit indices including root mean of squared error approximation, goodness of fit index and adjusted goodness of fit index were obtained 0.026, 0.96 and 0.92 respectfully. The correlation between the results measured with the questionnaire and VFM-90.1 device was −0.87. Cut-off points of the questionnaire were 0.65, 2.36 and 3.88. The confirmed questionnaire consists of four main areas: Eye strain (4 questions), visual impairment (5 questions) and the surface impairment of the eye (3 questions) and the out of eye problems (3 questions).

Conclusions: The visual fatigue questionnaire contains 15 questions and has a very remarkable validity and reliability. Using this questionnaire and its findings, one will be able to identify, assess and finally prevent the effective factors of VDT users' visual fatigue.

Keywords: Reliability, validity, visual fatigue questionnaire, visual display terminals

INTRODUCTION

Today in most of the work places such as nuclear, military and chemical industries a human error may lead to a disaster.[1] Human error is failing to comprehend the situation, information processing, making decision, re-reading the received data or simply failing to perform properly.

Obviously, physical or mental status of the individual, such as exhaustion and lack of attention, will be effective on the factors that will lead to the individual's lack of proper performance in time and place. Fatigue can narrow the scope of human focus and attention.[2] Mostly, fatigue is due to strain. Strain usually leads to stress and may cause irreversible changes if it is high or lasts for a long time. Most of the visual activities during the day are reasons for visual fatigue.[3] Computer is an inseparable part in today's human life.[4] At first, monitor radiation was the main focus of the researchers, which gradually got replaced with the visual complaints owing to working with monitors.[5] Working with computer terminals is closely related with visual disorders and can affect the individual's precision.[4] Several studies have proved that about 75% of computer users suffer from visual problems.[6,7]

Visual fatigue includes symptoms such as headache, alienation from work and eye pain.[8] The most common complaints reported in different studies carried out on visual terminal users include pain and pressure in the eye, dry eye, tearing, irritation and redness, blurred vision and double vision, neck pain, back and shoulders pain.[3,4] Visual fatigue symptoms and computer vision syndrome often largely overlap.[9] Providing and promoting the visual fatigue measurement follows a progressive trend. So far, a number of diverse one or multi-dimensional instruments have been manufactured to assess the amount of the intensity and fatigue level.[10] One of such tool is the visual fatigue meter (VFM), which is based on the flicker changes.[11,12] This device is an acceptable one as a means to evaluate the visual fatigue changes in ergonomics science.[13] Considering fatigue as an internal and mental experience, it deems necessary to take mental measurements more into account.[9] The other tool used by researchers to assess the visual fatigue is the subjective visual fatigue questionnaire by which mental parameters are converted into objective parameters.[13-16] In 2007, Kuze and Ukai produced a 28-item questionnaire including a list of visual fatigue symptoms in a scale of 7 and in 5 major areas.[9] In Lin YT *et al*. study in 2008, visual fatigue was simultaneously assessed with the Heuer's questionnaire and critical fusion frequency (CFF) index.[17] Ogata *et al.* presented a series of visual fatigue symptoms in their questionnaire.[18] Yano *et al.* assessed the Visual fatigue by a question in a scale of 5.[19,20] Such one item questionnaires along with other objective methods have been used to assess visual Fatigue simultaneously.[19,21]

So far, there have been some questionnaires presented to assess the visual fatigue of video display terminals (VDTs), but none of them has managed to classify it qualitatively or quantitatively; thus, researchers in this study have attempted to design such a comprehensive questionnaire to cover all those aspects of visual fatigue of the VDT operators using a physiologic parameter (CFF change) as a criterion to determine the cut-off points of visual fatigue.

METHODS

This study was run in 2011 and aimed at designing an appropriate tool to assess the visual fatigue in 248 of VDT operators in a wide range of professions (such as bank clerks, typists, secretariats, office workers, telephone operators and students) in order to find out the visual fatigue symptoms of the VDTs. Initially several scientific sources such as books, articles and similar questionnaires were studied to provide a comprehensive bank. Then the first draft of the questionnaire with the closed questions was designed and reviewed several times in order to have it checked grammatically as well as to make sure that all visual fatigue symptoms are included properly. To assess the face and content validity, the questionnaire was handed in to 7 experts to announce if the questions are related to the visual fatigue in Likert scale. Besides, the simplicity and comprehensibility of each question was announced by the experts. Then, content validity index (CVI) of each item was calculated. Questions with more than 0.75 CVI were remained and the rest were either modified or removed. Later on, the experts were asked to re-assess the CVI of the questionnaire again and finally the results were put in the last version of the questionnaire.[22] To determine the reliability of the questionnaire a pilot study with random sampling was done on 40 VDT professional users and its results were analyzed by $SPSS_{11.5}$ to confirm the Cronbach's co-efficiency and to remove the probable pitfalls of the questionnaire.

Based on some studies, visual fatigue and its affecting options are classified in four main areas (Eye strain, impaired vision, impaired surface eye and outside eye problems).[4,5] This theoretical pattern was accepted as the initial and assumed pattern and its construct validity was assessed by visual fatigue in 248 VDT users. The sample size was 252 (Using 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 minimize the risk of errors and prior to study, participants were examined in ocular health and uncorrected reflective errors. The participants involved in the test were also trained how to respond to the flickers of light emitting diode (LED). Then, the visual fatigue of each user was measured both before and after the test by both the questionnaire and VFM-90.1. The questionnaires were filled in the face to face by the researchers and the participants. To avoid the hawthorn effect, the participants were told that this is a scientific study that its results are to be published keeping the participants' privacy intact.

Visual fatigue measurement was performed in the following two steps:

Step 1: All participants were banned from any kind of eye work such as working in front of monitors, watching television and studying about 15 min prior to the study. Then, the visual fatigue of the users and their flicker value were measured by the use of the two above mentioned tools.

Step 2: After the first step, all participants returned to their jobs straightly and were busy at work for 60 min at least. Then, their eye fatigue and flicker value was measured and recorded. After collecting the data, the $AMOSE_{16}$ software was used to confirm or reject the pre-pattern four-factor visual fatigue questionnaire and fit indices (CMIN/dF, goodness of fit index (GFI), CFI, adjusted goodness of fit index (AGFI), root mean of squared error approximation (RMSEA)) were calculated. After having the questionnaire confirmed in terms of the face, content and construct validities, its reliability was measures as well. The Iranian VFM-90.1 device was used as the criterion for the quality check.

VFM-90.1

VFM-90.1 is composed of the two following parts: One is the central control box and the other is a 50-cm telescopic part which completely isolates the inside part of the telescopic part from its surrounding light. On one side of the telescopic part the user's eyes and on the other side a flashing light source with controlled frequency is located.

The light source or LED is turned off and on continually from 50 Hz to 1 Hz with a 4 s interval for each show. This device assesses the eye fatigue changes based on the CFF changes. CFF changes in turn determine the visual fatigue level of a certain job on the visual system. CFF index changes both before and after the treatment are acceptable indices to determine visual fatigue.[14] The analyzability of the VFM-90.1 device is 0.1 Hz and its error variation is 0.8.

To start the test and after having the user put his eye in the right place, the frequency of 42 was selected voluntarily and the participant was asked to press a manual key as he realizes the flickering on the LED. If the participant manages to realize the flickering, the initial frequency would be promoted to 45 Hz or more. The participant's pressing the key would record the flicker value on the device's display screen. The flicker value of all participants would be measured and recorded simultaneously in two stages. Data were sent to statistical $SPSS_{11.5}$ software. The questionnaire's value changes, the flicker's value changes and receiver operating characteristic (ROC) curve were used to obtain the cutting points of the questionnaire (no fatigue, low fatigue, moderate fatigue and severe fatigue). The three optimal cut-off points were identified using sensitivity, specificity, areas under the curve and significant level.

RESULTS

Some of the demographic features of the participants are presented in Table 1. Having the questionnaire reviewed, 4 of the participants were removed owing to their failure to meet the criteria. Of all the 248 participants in this study, 16.1%, 6.5%, 37.9%, 25.4% and 5.2% were bank clerks, office operators, typists, telephone operators and university students respectively. The age average and the standard deviation of the participants were 35.7 and 6.6 respectively while the mean and the standard deviation of the CFF were −1.25 and 0.995 Hz. The first version of the questionnaire was composed of 23 technical questions. To verify the face and content validity of the questionnaire, it was handed in to 7 experts. They were asked to declare their opinions if the questions are related to the topic under study, simplicity and comprehensibility of the questions using the CVI. All those items with 75% or less were either removed or revised in the questionnaire.

Table 1: Frequency distribution of demographic variables and some background of VDT users

Variables	Frequency	Percent
Job		
Bank clerks	40	16.1
Secretariat	16	6.5
Typists	94	37.9
Office worker	22	8.9
Telephone operator	63	25.4
Student	13	5.2
Sex		
Man	61	24.6
Woman	187	75.4
Education		
Pre-diploma	12	4.8
Diploma	91	36.7
High diploma and above	145	85.5
The use of eye glasses		
Yes	53	21.4
No	195	78.6
Displays		
LCD	157	63.3
CRT	91	36.7
Age (mean±SD)	6.6±35.73	
Distance from eye to monitor (cm) (mean±SD)	11.90 54.84	

VDT=Video display terminal, LCD=Liquid-crystal display, CRT=Cathode ray tube, SD=Standard deviation

In addition, a question was added to the questions in the original questionnaire, two were mixed into one and four of them were deleted as deemed by the experts, which have reduced the questions to 19. Then, the new questionnaire was sent to the authorities to be verified and confirmed again. The main categories were reduced to 15 after re-evaluating the CVI.

All answers were designed in to Likert (0-10). The initial reliability was assessed by a pilot study on 40 professional users of VDT and the Cronbach's co-efficiency was calculated 0.86. Besides, at the end of the study and after data collection the Cronbach's co-efficiency was assessed and reliability of each question was calculated by $SPSS_{11.5}$. The assumed pattern of the visual fatigue questionnaire was accepted in four main areas as follows:

- Eye strain consists of four sub-domains (questions 1, 4, 11, 14)
- Impaired vision includes five sub-domains (questions 7, 8, 12, 13, 15)
- Impaired eyes surface consists of three sub-domains (questions 2, 3, 5)
- Problems of the out eyes consist of three sub-domains (questions 6, 9, 10).

To confirm the structural validity of the questionnaire, $AMOS_{16}$ software and confirmatory factor analyze were used. The model fit indices were calculated. According to the results the initial model was confirmed with the following results:

P = 0.064, CMIN/dF = 1.31, CFI = 0.99, AGFI = 0.92, GFI = 0.96, RMSEA = 0.036

The highest score of changes recorded in visual fatigue (CFF changes) was assessed (−4.1) and the highest questionnaire changes were 5.83. The assessed visual fatigue was estimated by questionnaire on a Likert scale and CFF changes are based on the Hertz. The results correlation between tools was examined by the Pearson's correlation ($r = -0.87$ and $P < 0.001$).

Since no cut-off points have been reported in the previous studies for these two tools, the cut-off points were identified using the results of the measurements and by calculating the sensitivity and specificities and ROC curves. VFM-90.1 was used as the criterion to calculate the cut-off points in the questionnaire. The flicker variations in this study have been between (0) and (−4.1) Hz and all points in the variation range have been assumed from −0.2 to the next point with 0.1 interval, as the cutting points and a ROC curve was drawn for each of the sensitivity-specificity curves. Besides, all the areas under the curve and the significant levels were studied separately. Cutting points were determined based on the best sensitivity, specificity and the areas under the curve. The first cutting point was (−0.5) Hz that is the equal to 0.65 in the questionnaire based on Table 2 and Graph 1. In the second stage, using $SPSS_{11.5}$ the only values with less than (−0.5) was used in the test. Just like the previous stage all points in this point were considered the second cut-off point and ROC curves, sensitivity, specificity and the areas under the curves were calculated (with 0.1 interval), the second cut point was (−2.2) Hz that is the equal to 2.36 in the questionnaire based on Table 2 and Graph 1. To calculate the third cut-off point, the researchers did as in the other two stages, the samples less than (−2.2) Hz were selected and their ROC curves, sensitivity and specificity were calculated, as in Table 2 and Graph 1, the third cut point was (−3.4) that is the equal to 3.88 in the questionnaire.

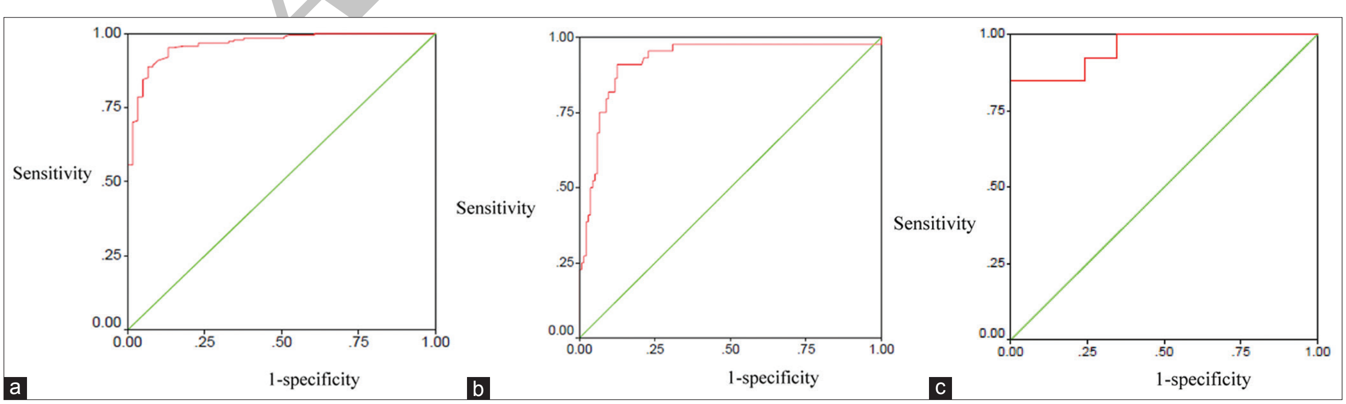
DISCUSSION

Based on the results, the 15-question visual fatigue of VDT users bears significant scientific validity and reliability. To compare the scientific construct of the present questionnaire, it can be compared with Kuze questionnaire (2007) that its designer identified 5 main areas after exploratory factor analysis, as fellows: Eye strain, general discomfort,

Table 2: Sensitivity and specificity values, cut-off points, visual fatigue zones

Tested cut-off points on VFM (Hz)	Area under curve (SD)	*P* value	Specificity	Sensitivity	Calculated cut-off point for the questionnaire	Visual fatigue zones (0-10)
−0.4	0.955 (0.013)	<0.001	0.900	0.894	0.57	No fatigue (≤0.65)
−0.5	0.964 (0.011)	<0.001	0.902	0.909	0.65	
−0.6	0.964 (0.011)	<0.001	0.882	0.900	0.68	Low fatigue (0.66-2.36)
−1.5	0.891 (0.025)	<0.001	0.824	0.808	1.52	
−2	0.913 (0.026)	<0.001	0.797	0.904	1.67	
−2.2	0.921 (0.027)	<0.001	0.875	0.909	2.36	
−2.5	0.911 (0.032)	<0.001	0.897	0.794	2.83	Moderate fatigue (2.37-3.88)
−3.2	0.897 (0.052)	<0.001	0.769	0.813	3.45	
−3.3	0.938 (0.035)	<0.001	0.875	0.800	3.6	
−3.4	0.955 (0.033)	<0.001	1.00	0.846	3.88	
−3.5	0.933 (0.041)	<0.001	0.967	0.833	3.89	Severe fatigue (≥3.89)

VFM=Visual fatigue meter, SD=Standard deviation



Graph 1: Receiver operating characteristic curves obtained for the three cut-off points, (a) The area under curve for cut-off point (−0.5Hz), equal to 96.4% ± 0.011, (P < 0.001), (b) The area under curve for cut-off point (−2.2Hz), equal to 92.1% ± 0.027, (P < 0.001), (c) The area under curve for cut-off point (−3.4 Hz), equal to 95.5% ± 0.033, (P < 0.001)

nausea, focusing difficulty and headache. Kuze questionnaire has very detailed questions. In the first draft of the present questionnaire, we had similar detailed questions, which were mixed in the content validity phase as deemed by experts. For example, all questions concerning frontal, occipital and temporal headaches were converted in to a single headache question that made our questionnaire easier to be answered by the participants. Beside it was tried to put all the visual fatigue symptoms in to the questionnaire. The distinguishing advantage of the present questionnaire composed with that of Kuze's is its qualitative and quantitative ability in distinguishing visual fatigue. Having studied the visual fatigue factors in the VDT users in 2005, Blehm *et al.* assessed the validity a questionnaire that categorized the visual fatigue into four main areas of: Eye strain, impaired eye surfaces, impaired vision and outside problems of the eye.[4] The present questionnaire similar to Blehm's based on structural models and content validity, but the present questionnaire is considered superior because of its ability to determine the levels of qualitative and quantitative aspects of visual fatigue.

Amalia and Artini in 2010 assessed visual fatigue of 99 computer-user students with a 15-question questionnaire. The questions were designed in Likert scale from 0 to 5, with a final score between 0 and 75.[23] Our questionnaire is designed in Likert scale from 0 to 10 to increase accuracy of answering questions. Besides, these two questionnaire are utterly different in terms of the final score domains, sub-domains and the number of cut-off points, but is the same due to the number of questions. The Amalia's questionnaire cut-off point (score 9, on a scale of 0-75) is almost equal to our first cut-off point (score 0.65, in the range of 0-10). One of the advantages of our questionnaire is its ability determine the three cut-off points for visual fatigue.

Heuer's *et al.* visual fatigue questionnaire has six questions with the10-scale Likert.[11] Its number of questions is limited and it seems not to be able to cover all the diverse aspects of visual fatigue. Besides, Heuer's questionnaire fails to determine visual fatigue qualitatively and quantitatively. Yano *et al.* used only a question to assess visual fatigue on the scale of 5.[19] Such single-choice questionnaires along with other objective methods can be used simultaneously to assess visual fatigue.[15,17] Assessing visual fatigue using only a question might lead to large errors. Hence, it is vital to use another method simultaneously which somehow asserts such a questionnaire's limits. Yano's questionnaire failed to present any qualitative and quantitative leveling in assessing visual fatigue.

Professional experts were consulted with to determine scientific validity of the visual fatigue questionnaire. The questionnaire's face and content validity were confirmed through scientific processes. It worth's mentioning that the possibility of categorizing the questions into four main areas was checked using confirmatory factor analyze. The four-factor theoretical pattern of visual fatigue was confirmed considering the fit indices. Finally, the questionnaire was confirmed considering its construct and content validity. Furthermore, Alpha Cronbach's was equal to 0.75 that significant the questionnaire's reliability. Besides, the existing correlation among the domains yielded a mild relationship ($0.5 < r < 0.25$), proving that the selected domains did not show any overlapping. Therefore, the mentioned questionnaire showed internal integrity.

The simultaneous assessment of visual fatigue variations (both prior to and after the test) using the tools, led to a negative correlation ($r = -0.87$ and $P < 0.001$), it means that the more visual fatigue score, the less the individual flicker value frequencies. The mention correlation proves the ability of the both tools in assessing the visual fatigue changes.[24-29]

Having the questionnaire's score variations and the flicker values (CFF changes) for every individual, the sensitivity-specificity values and the area under the curves, the visual fatigue cut-off points were obtained as follow in three stages of (−0.5), (−2.2) and (−3.4) Hz, the three obtained scores of the questionnaire were equal to 0.65, 2.36 and 3.88 respectively.

The visual fatigue zones were determined as in Table 2. The following domains of less than 0.65, (0.66-2.36), (237-3.88) and more than 3.88 show the no fatigue, low fatigue, moderate fatigue and severe fatigue domains respectively.

CONCLUSIONS

This questionnaire in hand is the first one in kind in the visual fatigue domain using a physiological parameter (CFF changes). Considering the fact that the physiological parameter are responded the same in all human societies, it could be claimed that this 15-question questionnaire bears an acceptable and also scientific validity and reliability, using this questionnaire and its results. The effective factors in visual fatigue of VDT users could be identified, assessed, controlled and prevented. Preventing the visual fatigue, the user's accuracy will be enhanced and will prevent and control the work accidents resulting from visual fatigue.

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