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Ergonomics Design Criteria of a Virtual Environment

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1. Introduction

Virtual environment (VE) can be defined as a computer generated three dimensional model environment; in which a user feels as if he/she is present in it and the user can interact intuitively with objects contained within it (Wilson, 1999). While being advantageous in experiencing new environment without having to build the real thing, the experience comes with some side effect for some. When interacting with VE through output and input devices, it has been reported that some users experienced negative side effects by being immersed into the graphically rendered virtual worlds. One of side effect is known as cyber sickness i.e. especially affecting the vision (Stanney *et all*, 1998; Barret, 2004). Stanney *et all* (1998) further mentioned that for VEs to be effective and well received by their users; while avoiding unwanted side effect, human being's limitation needs to be considered during the VE design stage. It is highly essential to ensure that advances in VE technology will not be at the expense of human well being.

Ergonomics is a branch of science that is concerned with the achievement of optimal relationship between workers and their work environment (Tayyari, F. and Smith, J.L., 1997). Since human being's limitation is crucial in the design process of a virtual environment, implementation of ergonomics will bring about an optimal VE experience for users. Good design incorporating ergonomics consideration will enhance the communication between the user and the virtual world. Since several ergonomic factors contribute to good VE design, there is a need to investigate what are the critical ergonomics design criteria.

Most ergonomics researches are related to the ergonomic design criteria of human computer interaction. They are focused on physical ergonomics such as visual display terminal (VDT). Stewart, T. (1995) exhibited the importance of ergonomics standards for computer equipment (IS0 9241), and the necessity in understanding how to use them when selecting or designing visual display unit (VDU) equipment and systems**.** When Menozzi, M., *et al* (1999) conducted studies comparing cathode ray tube (CRT) display and liquid crystal display (LCD) for their suitability in visual tasks in VDU, it was found that LCD provided better viewing conditions compared to CRT display. Nichols, S. (1999) investigated the design of VR equipment in respect to the physical ergonomics such as head mounted display (HMD) and hand-held input devices and the problems associated with it. Shieh and Lin (2000) investigated the effect of screen type, ambient lighting and colour combination on VDT to visual performance and found that those factors do affect VDT performance. Lin (2003) studied the effects of contrast ratio and text colour on visual performance using TFT-LCD and found that contrast ratio significantly affects visual performance. In 2007, after being approved by ANSI on 14th November, the Human Factor Engineering Society published the new national standard for human factor engineering of computer workstation (ANSI/HFES100), which eventually becomes the comprehensive ergonomics guideline in the design of a VDT.

Ergonomics research related to virtual environment has been conducted in the past, but the focus of the research is only on the use of VE as a tool in ergonomics analysis (Shaikh,I., *et al*, 2004; Colombo and Cugini, 2005; Pappas, M., *et al*, 2005; Dukic, T., *et al,* 2007; Hu, B, *et al*, 2011). Shaikh,I., *et al*, (2004) studied on participatory ergonomics using VR and found that VR system will help towards designing better workplaces. Colombo and Cugini (2005) researched on virtual humans and prototypes, evaluating ergonomics and safety. While Pappas, M. *et al* (2005) investigated on ergonomic evaluation of virtual assembly tasks. Other researchers such as Dukic, T *et al* (2007) researched on the evaluation of ergonomics in a virtual manufacturing process and Hu, B. *et al* (2011) presented preliminary experimental results on the relationship between ergonomic measurements in VE and RE for some typical "drilling" tasks.

It has been noted that no research on ergonomics design criteria for designing a virtual environment has been reported. Thus, the objective of this study in identifying the ergonomics design criteria for designing a Virtual Environment is imperative.

2. Material and methods

2.1 Subjects

Eight university students participated in the study. None of the participants suffered from any vestibular and visual dysfunction and were not taking any medication during the experiments. The mean age was 21.7 years old (aged 19-23 years). Prior to the experiment, informed consent was obtained about the nature of the experiment and the objectives of the experiment as well as participant rights were fully explained. Participants were tested individually during the entire experiment session and received payment for their participation. Ishihara plates for Pseudo Isochromatic test were used to test normal visual of a subject. The test for colour blindness was adapted from Courtney (1986).

2.2 Apparatus

2.2.1 Virtual stimulus

The virtual stimulus system used is a virtual robot manufacturing system (from here onwards to be referred only as the virtual environment (VE)). This Virtual Environment presents a virtual robot activity for storage loading and unloading (SLU) process (shown in Figure 1). It was developed using direct X and Dark Basic Professional. The Autodesk 3DS Max software was used to build the virtual object. The VE was displayed through a projector on a wide screen. The projector was connected via cable to a laptop controlled by a keyboard and mouse. This wide screen allows the projection of stereoscopic images where each eye will see the slightly shifted images.

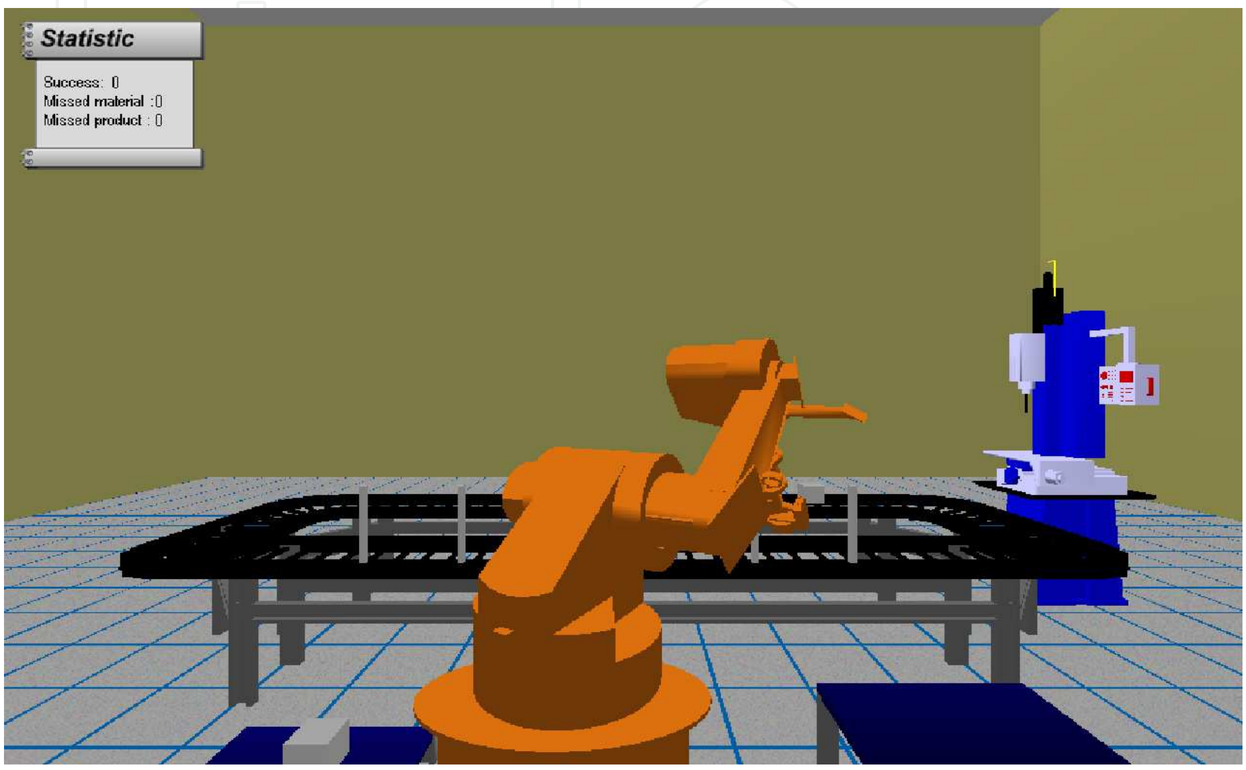


Fig. 1. Snap shot of Virtual Robot Manufacturing System

2.2.2 Questionnaires

A qualitative assessment was conducted through the use of questionnaire. The questionnaire was developed to identify the visual symptoms of the virtual environment variables / attributes investigated. The questionnaire consists of two principal parts. The first part contains the question with seven response option. This is aimed to identify the visual problems experienced during or after interacting with the VE. The second part contains questions to identify the level of symptoms experienced based on the answers of the previous part. The answers to the questions in the second part were of the ordinal data type.

2.2.3 Statistical analysis

Statistical analysis was conducted to analyse the effect/relationship between independent variable and dependent variable. Non parametric statistic was implemented involving descriptive statistic and statistical binomial test. The tests were on hypotheses about the effect of each attributes or variables of the virtual environment on the incidence of visual symptoms. The hypotheses developed were:

- H1: Colour of background has effect of visual symptoms among immersive environment users
- H2: Virtual lighting has effect of visual symptoms among immersive environment users
- H3: Field of View (FOV) has effect of visual symptoms among immersive environment users
- H4: Flow rate (FR) has effect of visual symptoms among immersive environment users
- H5: Speed of virtual object motion has effect of visual symptoms among immersive environment users
- H6: Resolution of display has effect of visual symptoms among immersive environment users
- H7: Contrast ratio has effect of visual symptoms among immersive environment users

The level of significance was set at $\alpha = 0.05$ for all analyses.

2.3 Experimental design and procedure

2.3.1 Experimental design

The experiments were conducted at the ergonomic-virtual reality laboratory. A sitting position was adopted with the subject sitting at a distance of 15 – 25 cm from the back edge of the table to complete the task. The activity is to operate a virtual robot in the VE using an infrared mouse (wireless mouse) with the motion observed on the wide screen display.

The digital projector was positioned on a table 75 cm in height with an inclination angle of between 5^o-10^o with respect to the horizontal axis. The projector was connected to laptop with a display set to 1280 x 800 pixels. The distance from the front edge of the table or the digital projector to the center of the wide screen was 300 cm. The size of wide screen display is 170 cm in length and 155 cm in width. The bottom edge of wide screen display was measured at 94 cm above the floor. Prior to conducting the experiment, the subjects were made to adjust their seating positions to make them as comfortable as possible.

2.3.2 Experimental procedure

The subjects were provided with information describing the aims of the study and how the experiment will be conducted. Their health condition and past experience of sickness were also identified and their anthropometric data measured. The colour blind test was then conducted before proceeding to colour selection and the experiment. If a subject cannot complete the test, it means that the subject has some visual problems and is unable to continue the experiment.

Prior to performing the experiment, subjects were trained on how to use the wireless mouse in order to operate the virtual robot in the VE to complete the virtual task. Heart rate and visual acuity was measured before and after the experiment.

In the experiment, subjects were exposed to the virtual environment to view and operate a virtual robot by using a wireless mouse; to pick up a virtual material in a rack and to put it on a conveyor and subsequently to also pick up a virtual product on the conveyor and store in another rack as shown in Fig. 1. The activity was performed for 10 minutes for each attributes and for every subject of the VE studied. All subjects were required to sit in an upright posture and also in a comfortable posture while completing the virtual task. Participants were also instructed to complete the questionnaire immediately after finishing the virtual task.

3. Results

3.1 Effect of colour of virtual background to visual symptoms

Table 1 shows the results of the experiment describing the effect of colour of the virtual background on visual symptoms of the subjects. There are five types of colour used in this experiment, which are Red, Fuchsia, Dark Sky Blue, Medium Slate Blue and White. The colours were identified on the basis of user's preferences. Statistical binomial test at 5% significant level shows that the overall background colour has an effect on the user i.e. eyestrain and blurred vision syndrome. The eyestrain syndrome was experienced by 75% of users when Red and White background colours were used while 63% was experienced by the users when Fuchsia, Dark Sky Blue and Medium Slate Blue background colours were used. The blurred vision syndrome was only experienced by users when Red background colour was used.

No.	Colour	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
1.	Red	75 63	Eyestrain Blurred Vision	0.633 0.321	Effect Effect
2.	Fuchsia	63	Eyestrain	0.321	Effect
3.	Dark Sky Blue	63	Eyestrain	0.321	Effect
4.	Medium Slate Blue	63	Eyestrain	0.321	Effect
5.	White	75	Eyestrain	0.633	Effect

$p > 0.05$; N = 8

Table 1. Result of Experiment and Binomial Test of Visual Symptoms of Colour Virtual Background

No.	Level of Brightness	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
1.	10% level	83 50	Eyestrain Dry and Irritated Eyes	0.534 0.169	Effect Effect
2.	25% level	83	Eyestrain	0.534	Effect
3.	50% level	83	Eyestrain	0.534	Effect
4.	100% level	100 67 50	Eyestrain Dry and Irritated Eyes Light Sensitivity	0.178 0.138 0.169	Effect Effect Effect

$p > 0.05$; N = 8

Table 2. Result of Experiment and Binomial Test of Visual Symptoms of Virtual Lighting

3.2 Effect of virtual lighting to visual symptoms

The results of experiments on the effect of virtual lighting on visual symptoms are presented in Table 2. The experiment was conducted for four level of brightness of virtual light from darkest (10% level) to the brightest (100% level). The result of statistical binomial test at 5% significant level exhibiting the different effects of visual symptoms experienced by users is shown in Table 2. Eyestrain symptom was experienced by 83% of the users for all level of brightness. Whereas 50% the users experienced symptoms of dry and irritated eyes at 10% level of brightness and light sensitivity at 100% level of brightness. At the highest level of brightness, dry and irritated eyes were experienced by 67% of the users.

3.3 Effect of field of view

Table 3 presents the result of experiment on the effect of field of view (FOV). There are two types of FOV namely 120^0 and 85^0 FOV. Statistical binomial test at 5% significant level shows the same result of visual symptoms effect experienced by users but at different proportion especially the eyestrain and dry and irritated eyes symptoms. For 120 degree of FOV, 63% of the users experienced dry and irritated eyes while only 50% of the users experienced it for 85 degree of FOV. 75% of the users experienced eyestrain symptom at 85^0 of FOV and 50% of the users experienced it at 120^0 of FOV.

No.	Degree of FOV	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
1.	FOV 120^0	50	Eyestrain	0.114	Effect
		50	Blurred Vision	0.114	Effect
		63	Dry and Irritated Eyes	0.321	Effect
2.	FOV 85^0	75	Eyestrain	0.633	Effect
		50	Blurred Vision	0.114	Effect
		50	Dry and Irritated Eyes	0.114	Effect

$p > 0.05$; N = 8

Table 3. Result of Experiment and Binomial Test of Visual Symptoms of Field of View

3.4 Effect of flow rate of virtual object

Table 4 shows the result of experiments on the effect of flow rate (FR) of virtual object on visual symptoms of the subjects. There are two types of flow rate studied, which are five

No.	Flow Rate (FR)	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
1.	Flow Rate 5 (FR5)	75	Eyestrain	0.633	Effect
		50	Dry and Irritated Eyes	0.114	Effect
2.	Flow Rate10 (FR10)	75	Eyestrain	0.633	Effect
		50	Blurred Vision	0.114	Effect
		50	Dry and Irritated Eyes	0.114	Effect

$p > 0.05$; N = 8

Table 4. Result of Experiment and Binomial Test of Visual Symptoms of Flow Rate (FR) of Virtual Object

second per piece (FR 5) and ten second per piece (FR 10); corresponding to virtual object in sight every five second and ten second respectively. Statistical binomial test at 5% significant level shows that both types of flow rates have an effect on the users, in which 75% of the users experienced symptoms of eyestrain and 50% of the users also experienced blurred vision and dry and irritated eyes symptoms.

3.5 Effect of speed of virtual object motion

Table 5 shows the result of the experiment on the effect of speed of virtual object on the subjects. Two levels of speed were investigated, that is slow motion (0.050) and fast motion (0.100). The result of statistical binomial test at 5% significant level proves that both speeds have an effect to the users where both slow and fast motion caused the same visual symptoms i.e. eyestrain, blurred vision, and dry and irritated symptoms.

No.	Level of Speed	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
1.	Low Speed	83	Eyestrain	0.534	Effect
		50	Blurred Vision	0.169	Effect
		67	Dry and Irritated Eyes	0.466	Effect
2.	High Speed	75	Eyestrain	0.633	Effect
		50	Blurred Vision	0.114	Effect
		50	Dry and Irritated Eyes	0.114	Effect

$p > 0.05$; N = 8

Table 5. Result of Experiment and Binomial Test of Visual Symptoms of Speed of a Virtual Object

No.	Level of Resolution	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
			LCD		
1.	High Resolution	56	Eyestrain	0.166	Effect
2.	Medium Resolution	89	Eyestrain	0.300	Effect
3	Low Resolution	56	Eyestrain	0.166	Effect
			CRT		
4.	High Resolution	67	Eyestrain	0.399	Effect
5.	Medium Resolution	67	Eyestrain	0.399	Effect
		56	Dry and Irritated Eyes	0.166	Effect
6.	Low Resolution	67	Eyestrain	0.399	Effect
		56	Dry and Irritated Eyes	0.166	Effect

$p > 0.05$; N = 8

Table 6. Result of Experiment and Binomial Test of Visual Symptoms of Resolution of Display Type

3.6 Effect of resolution of display type to visual symptoms

Table 6 shows the result of experiment on the effect of display resolution on the subjects. Three level of resolution were investigated for both the liquid crystal display (LCD) and cathode ray tube (CRT) displays, which are high resolution, medium resolution and low resolution. The result of statistical binomial test at 5% significant level found that the overall level of resolution using either the LCD or CRT displays causes eyestrain symptoms to the users with more than 56% experiencing eyestrain. Others effect such as dry and irritated eyes symptoms were experienced by 56% of users when interacting with medium and low resolution CRT display.

3.7 Effect of contrast ratio

The result on the effect of contrast ratio to visual symptoms is described in Table 7. There are three kind of contrast ratio investigated. They are -50.83%, +24.58% and 0%. The ratio can vary from 100% (positive) to zero for targets darker than the background, and from zero to minus infinity (-∞) for targets brighter than the background (Grether and Baker, 1972). Statistical binomial test at 5% significant level shows that all contrast ratios causes eyestrain symptoms (75% of users). Blurred vision and dry and irritated eyes symptoms were experienced by 63% and 50% of users at contrast ratios of --50.83% and 0% (or -0.56%) respectively.

No.	Ratio of Contrast	Observation Proportion (%)	Symptoms	Exact Sig. (1-tailed)	Decision
1.	-50.83%	75	Eyestrain	0.633	Effect
		63	Blurred Vision	0.321	Effect
2.	+24.58%	75	Eyestrain	0.633	Effect
3.	0% (-0.56%)	75	Eyestrain	0.633	Effect
		50	Dry and Irritated Eyes	0.114	Effect

$p > 0.05$; N = 8

Table 7. Result of Experiment and Binomial Test of Visual Symptoms of Contrast Ratio

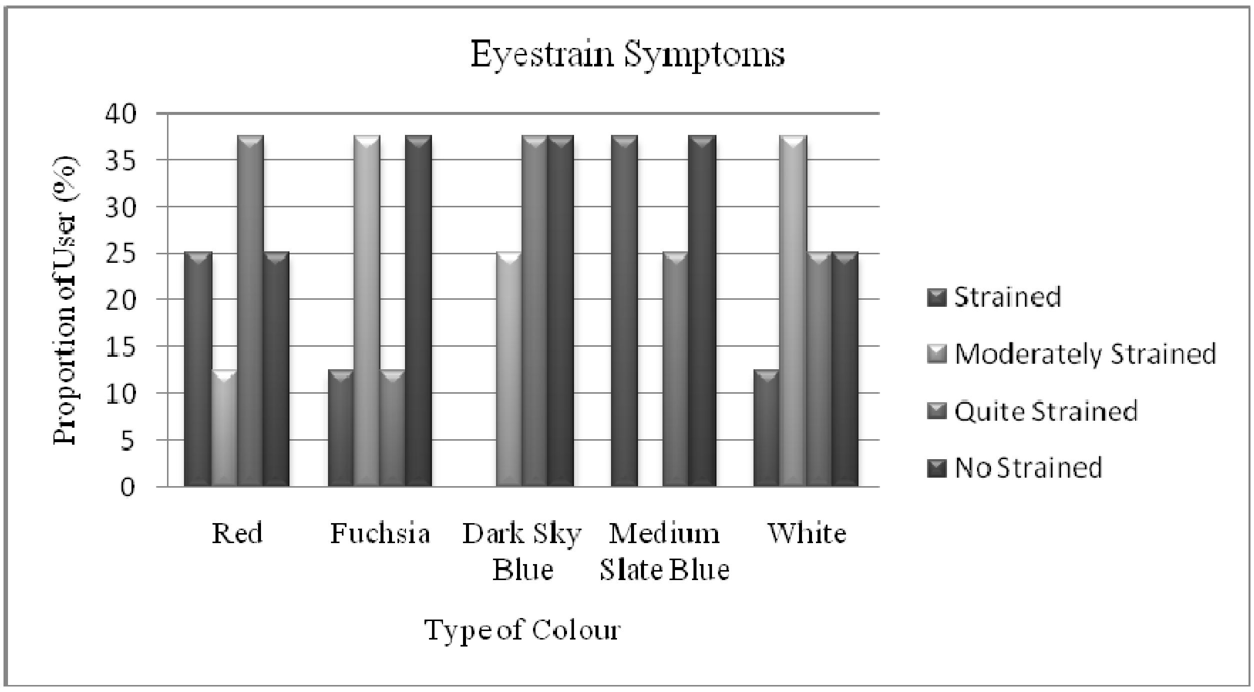
4. Discussion

One of the parameters of cyber sickness is visual symptoms (Barret, 2004). In his handbook, Anshel, J. (2005) mentioned that visual symptoms can vary but these mostly include eyestrain, headache, blurred vision, dry and irritated eyes, double vision, colour distortion and light sensitivity. The symptom most often occurs when the viewing demand of the task exceeds the visual abilities of the user. The viewing task is influenced by the design of the virtual environment viewed or interacted. This research has identified some attributes or variables of the VE that may cause the occurrence of visual symptoms.

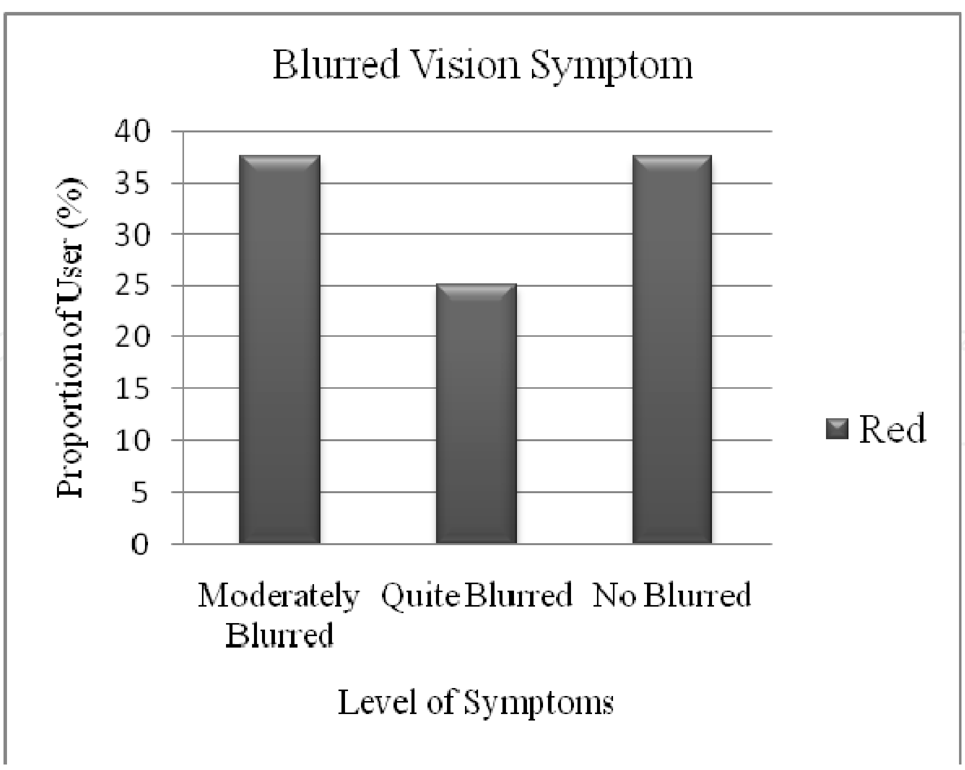
4.1 Analysis of the colour types for the virtual background design

Statistical binomial test on five types of colour of virtual background (Table 1) shows that the colour type inflicts the users with eyestrain and blurred vision symptoms. Fig. 2 (a) and

(b) exhibit the levels of eyestrain and blurred vision symptoms experienced by users when interacting with the VE. Only the red colour significantly resulted in blurred vision. This might be caused by the red colour causing discomfort to the eyes when a virtual object is in motion. The colour is also quite glaring in such a way that it would be difficult for the eyes



(a)



(b)

Fig. 2. (a) Level of eyestrain symptoms (b) Level of blurred vision symptoms

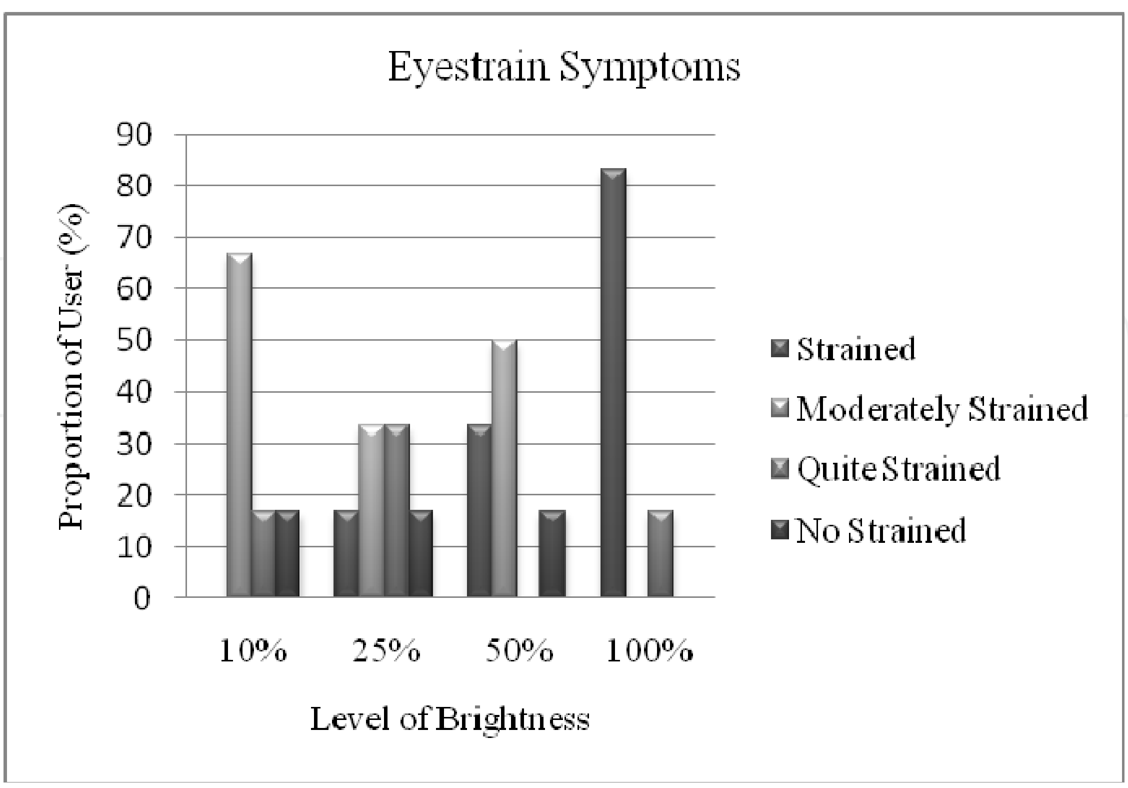
to focus on a virtual object. Others types of colours also generally causes eyestrain symptoms. Ergonomics recommendation on background colours stipulates the use of a design that is able to reduce or minimize the incidence of visual symptoms. No strain and no blur level is the target in the design of the background colour. Thus Red, Fuchsia, Dark Sky Blue, Medium Slate Blue and White colours must be changed to a smoother and softer colour type that can alleviate visual symptoms incidence.

4.2 Analysis of the virtual lighting level

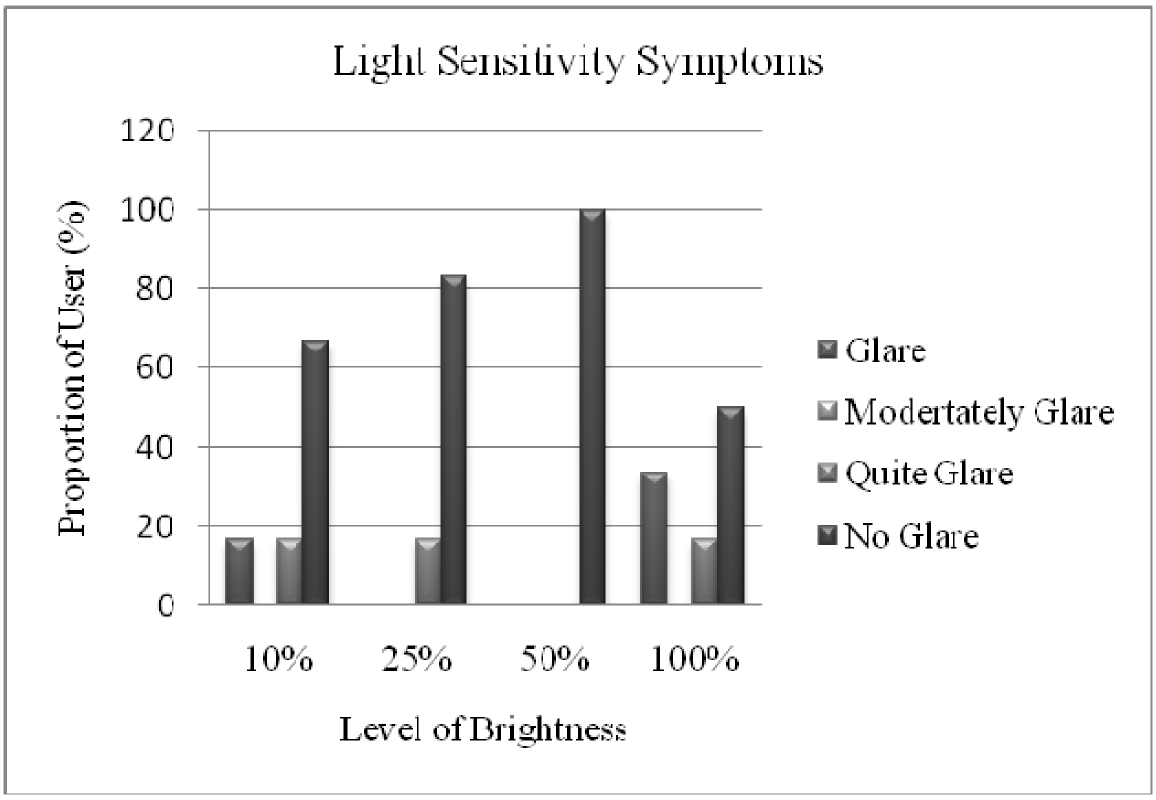
Results of statistical binomial test in Table 2 demonstrated the effect of brightness level of the virtual light on the occurrence of visual symptoms incidence. The level of brightness affects the eyes when tracking virtual objects in the VE. A darker light level (10%) or higher bright level (100%) can induce eyestrain and dry and irritated eyes symptoms as well as light sensitivity symptom. This is because the eyes are forced to focus causing strain to the eyes as well as dryness and irritation and decrease the sensitivity to light. Fig.3 (a), (b) and (c) describes the level of symptoms occurring in the human visual system. No effect (no strained, no dry, no glare) is the best condition of virtual lighting to be considered as one of the attributes in designing a VE.

4.3 Analysis of the effect Field of View (FOV)

Table 3 is the result of statistical binomial test of the effect of field of view (FOV) on users. It shows that the degree of visual field can develop incidence of visual disorder especially eyestrain, blurred vision and dry and irritated eyes. Therefore the degree of FOV has to be taken into account when designing a VE. It can be seen that 120^0 of FOV causes 50% of the users to suffer eyestrain symptoms as compared to the 85^0 of FOV. On the other hand, dry



(a)



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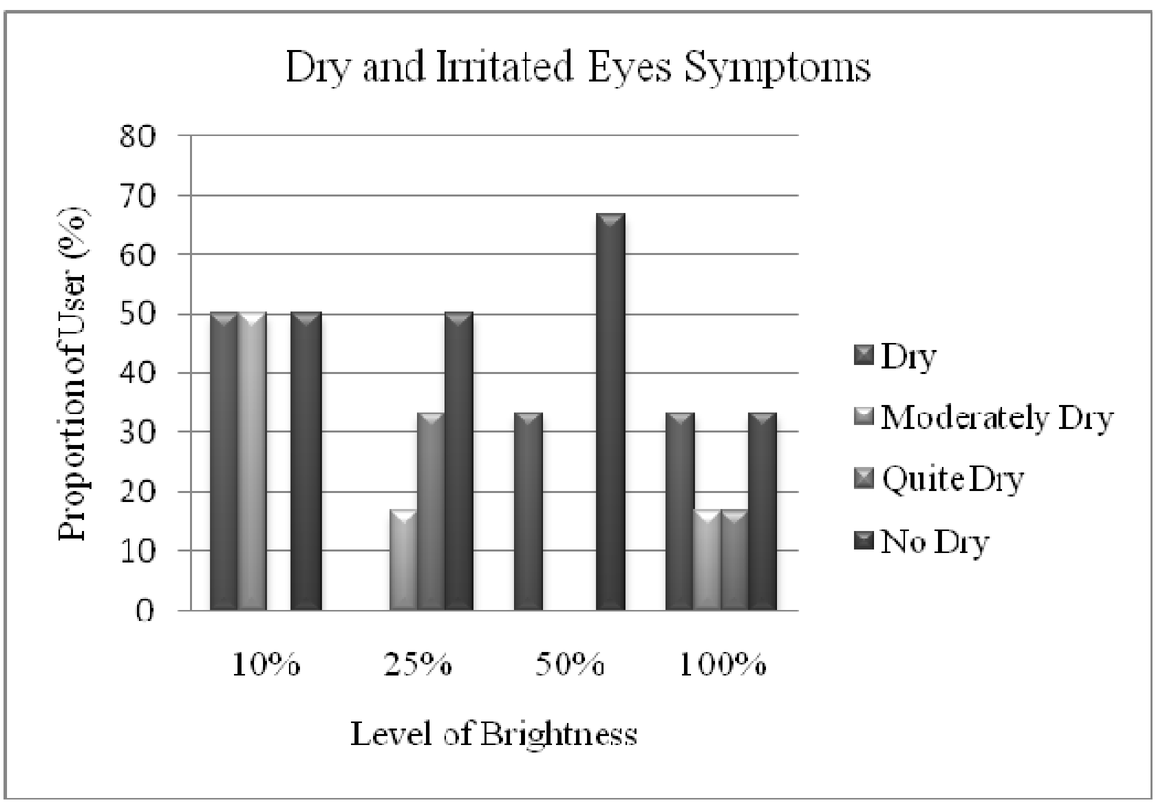


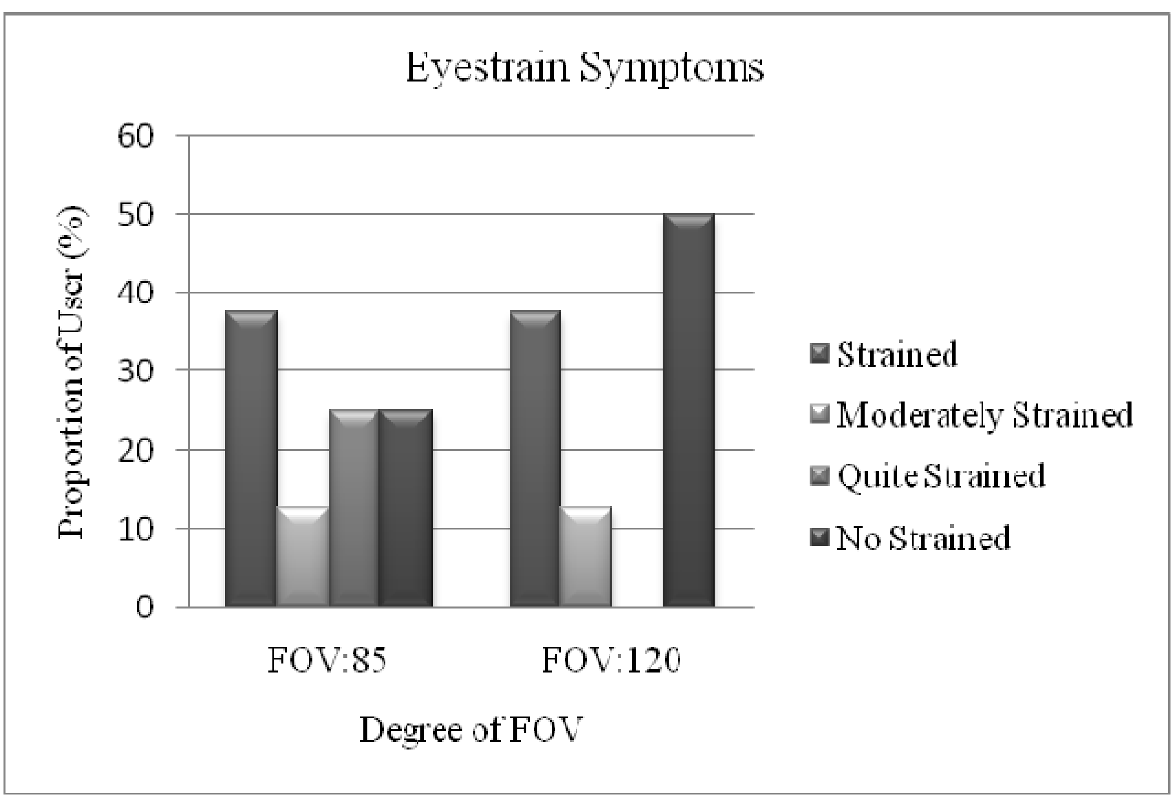
(c)

Fig. 3. (a) Level of eyestrain symptoms (b) Level of Light Sensitivity symptoms (c) Level of dry and irritated eyes symptoms

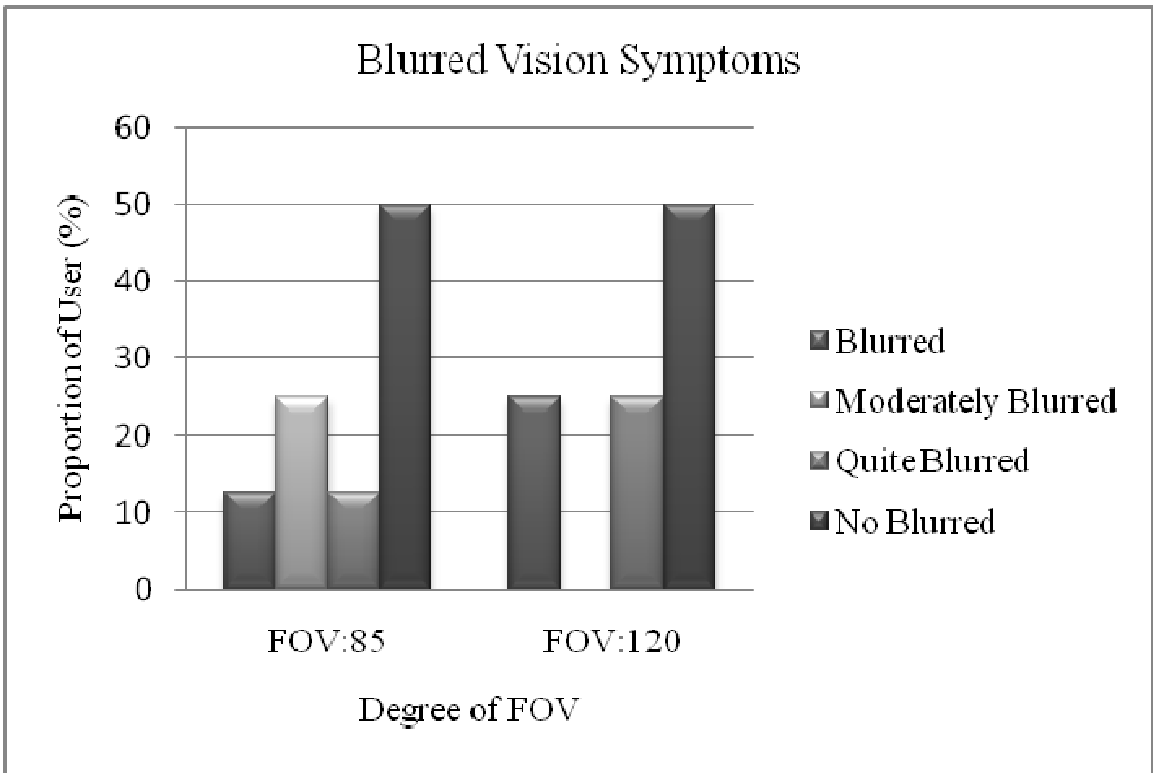
and irritated eyes symptoms were experienced by 63% of the users when using 120^0 of FOV higher than they were using 85^0 of FOV. Thus a wider of FOV or narrower of FOV will cause users to suffer one of the visual symptoms. It is because of both conditions require the eyes to focus. Thus it is essential to determine what FOV is required to reduce these symptoms. Fig.4 (a), (b) and (c) describes the levels of symptoms occurring for eyestrain, blurred vision and dry and irritated eyes symptoms respectively. For the eyestrain symptoms, 120^o of FOV is better than 85^o because about 50 % users did experience any incidence. On the contrary, 120^o of FOV is not acceptable compared to 85^o for dry and irritated eyes symptoms. This is because 50% of users did not experience any eye symptoms when using 85^o of FOV.

4.4 Analysis of the Flow Rate (FR) of the virtual objects

Flow rate (FR) is the rate at which subsequent flow of the virtual object can be generated per unit time. Result of statistical binomial test in Table 4 have found that the flow rate of virtual object have the effect on the incidence of eyestrain, blurred vision and dry and irritated eyes symptoms. This is because it affects the ability of the eyes to see the virtual objects as it is being generated so that the eyes experienced strain, blur and also dryness or irritation during that period. Fig. 5 (a), (b), and (c) depict the level of the symptoms experienced by users. The effect can be minimized by designing the appropriate flow rate of the virtual object generated. A flow rate at 5 seconds per piece is better than a flow rate of 10 seconds per piece to avoid blurred vision symptoms. This is because more than 69% of users do not suffer this condition at this flow rate.



(a)



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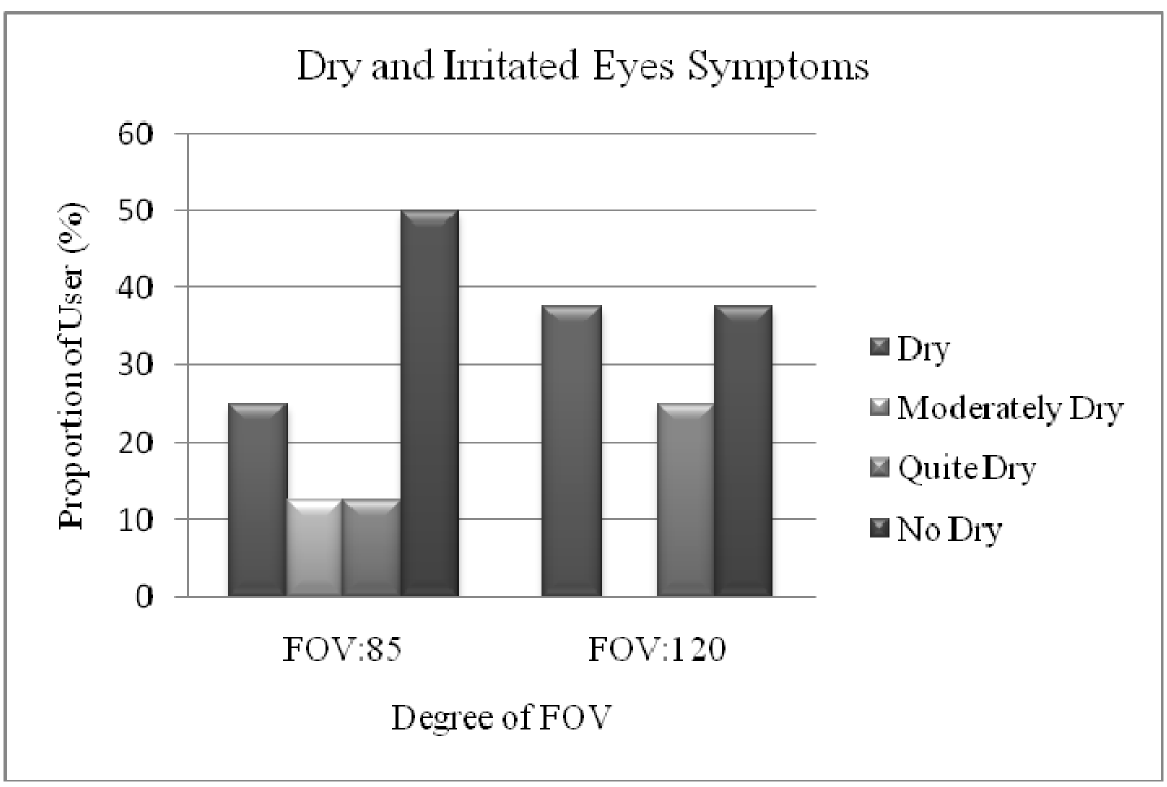
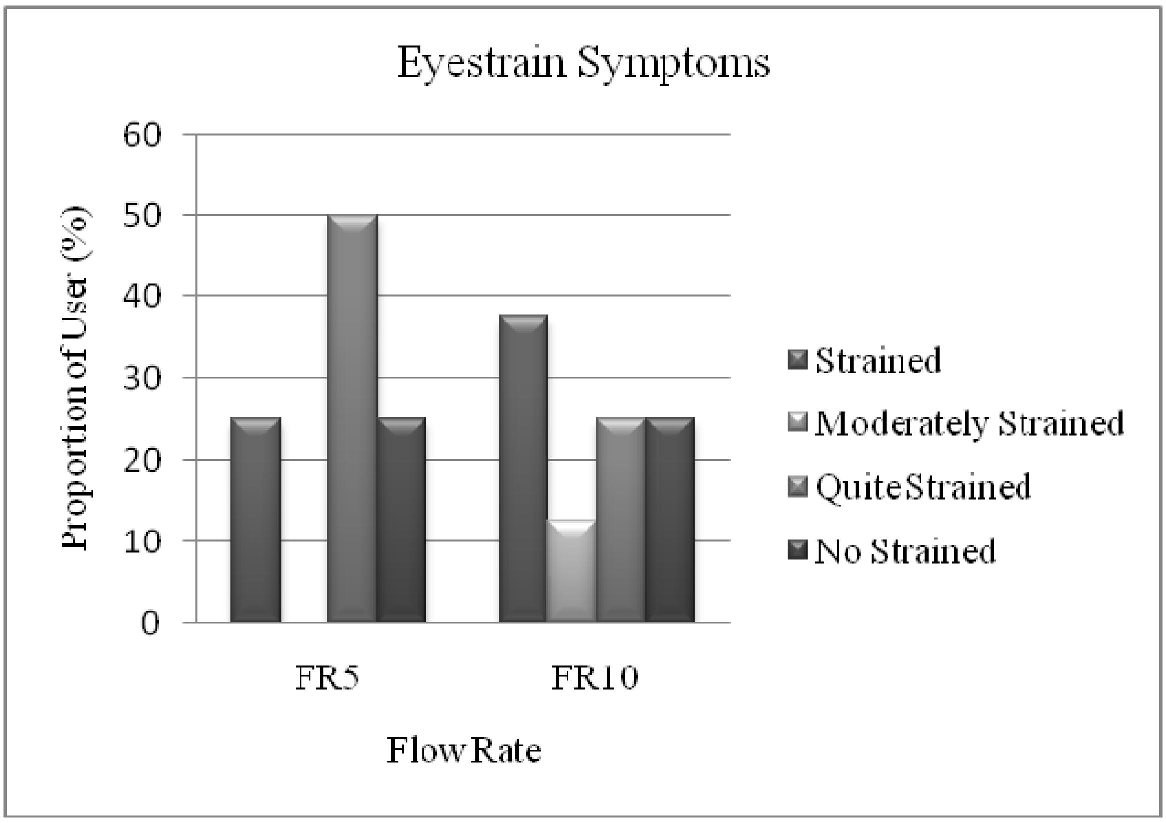
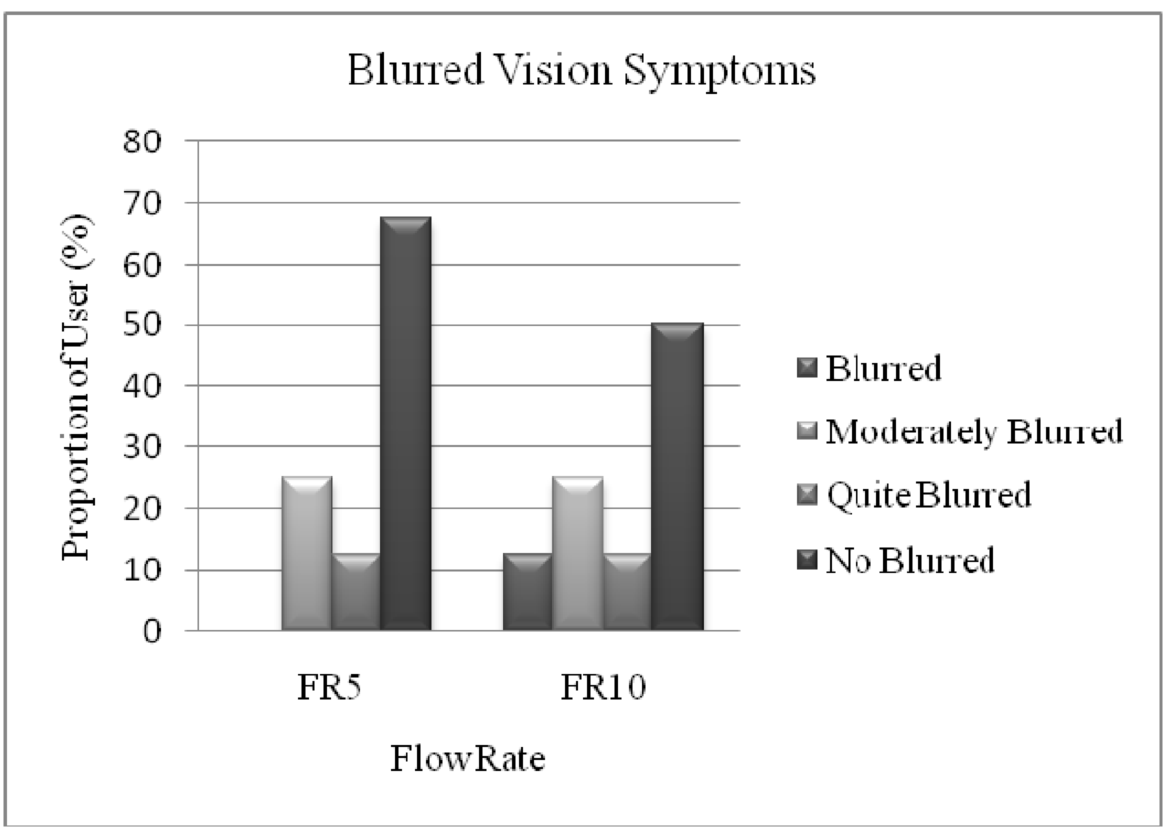


(c)

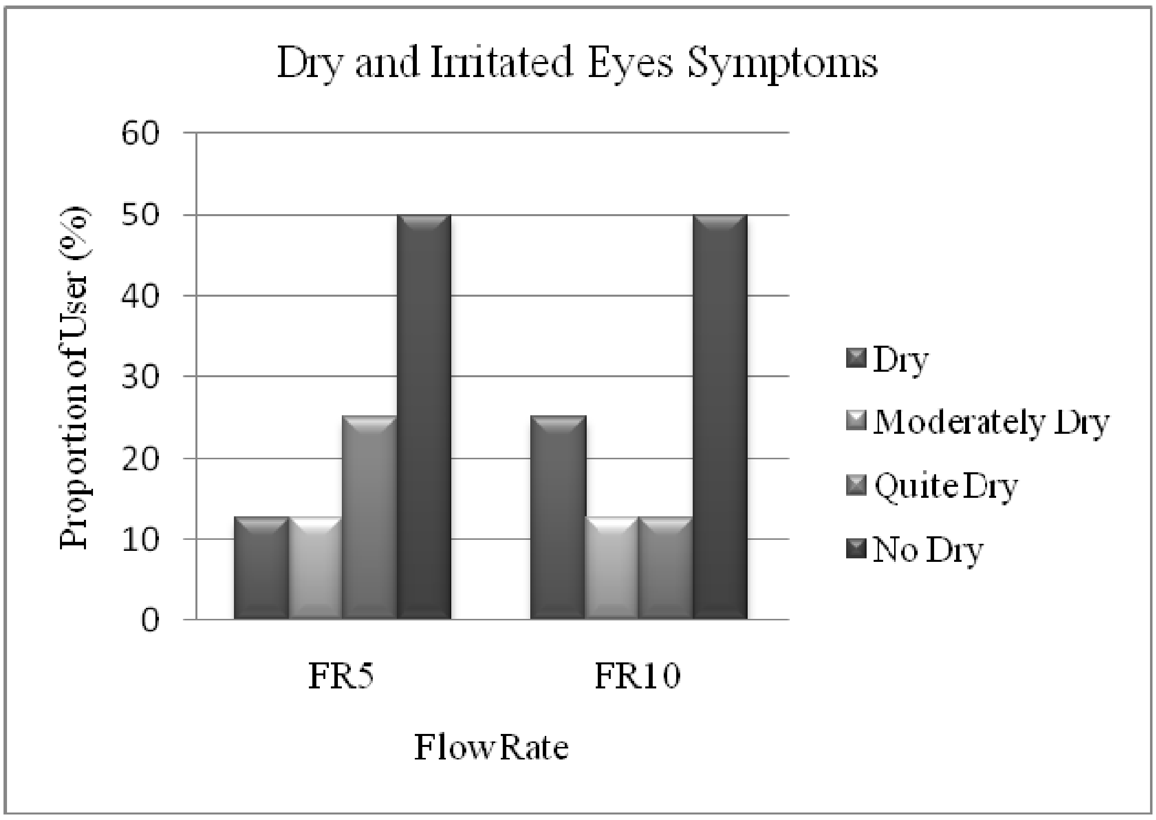
Fig. 4. (a) Level of eyestrain symptoms (b) Level of blurred vision symptoms (c) Level of dry and irritated eyes symptoms


Eyestrain Symptoms
60
50
40
30
20
10
0
Proportion of User (%)
FR5
FR10
Flow Rate
Strained
Moderately Strained
Quite Strained
No Strained

(a)


Blurred Vision Symptoms
80
70
60
50
40
30
20
10
0
Proportion of User (%)
FR5
FR10
Flow Rate
Blurred
Moderately Blurred
Quite Blurred
No Blurred

(b)



(c)

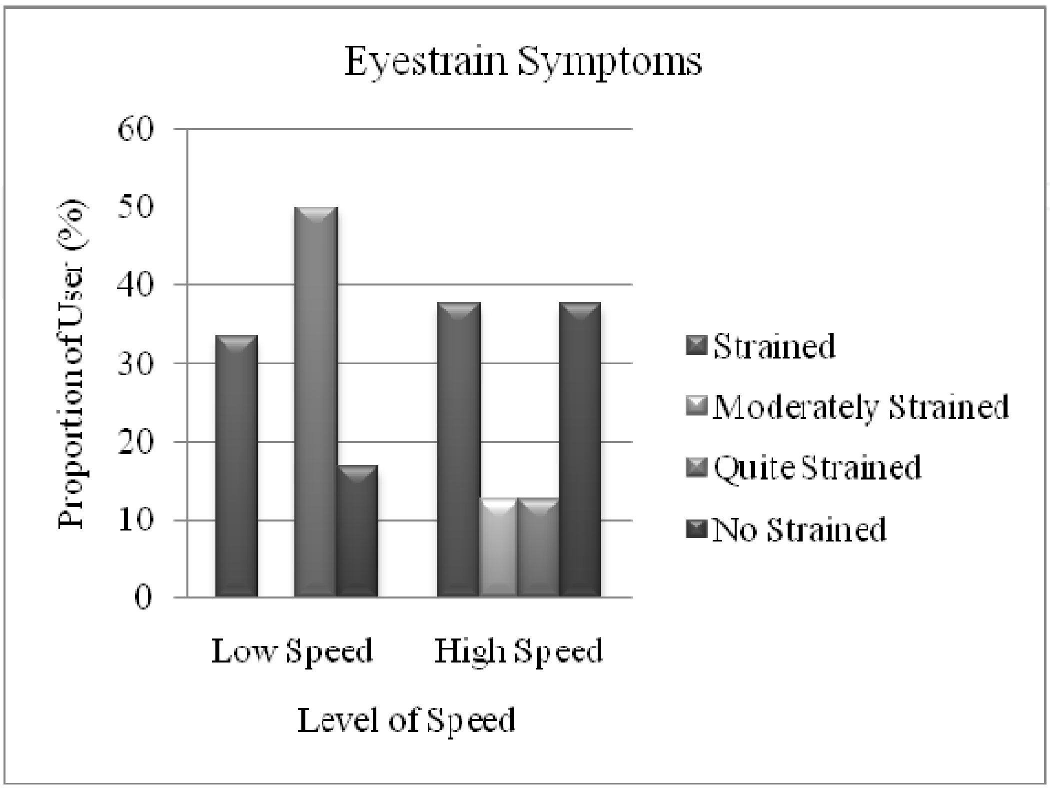
Fig. 5. (a) Level of eyestrain symptom (b) Level of blurred vision symptoms (c) Level of dry and irritated eyes symptoms

4.5 Analysis of the speed of the virtual objects motion

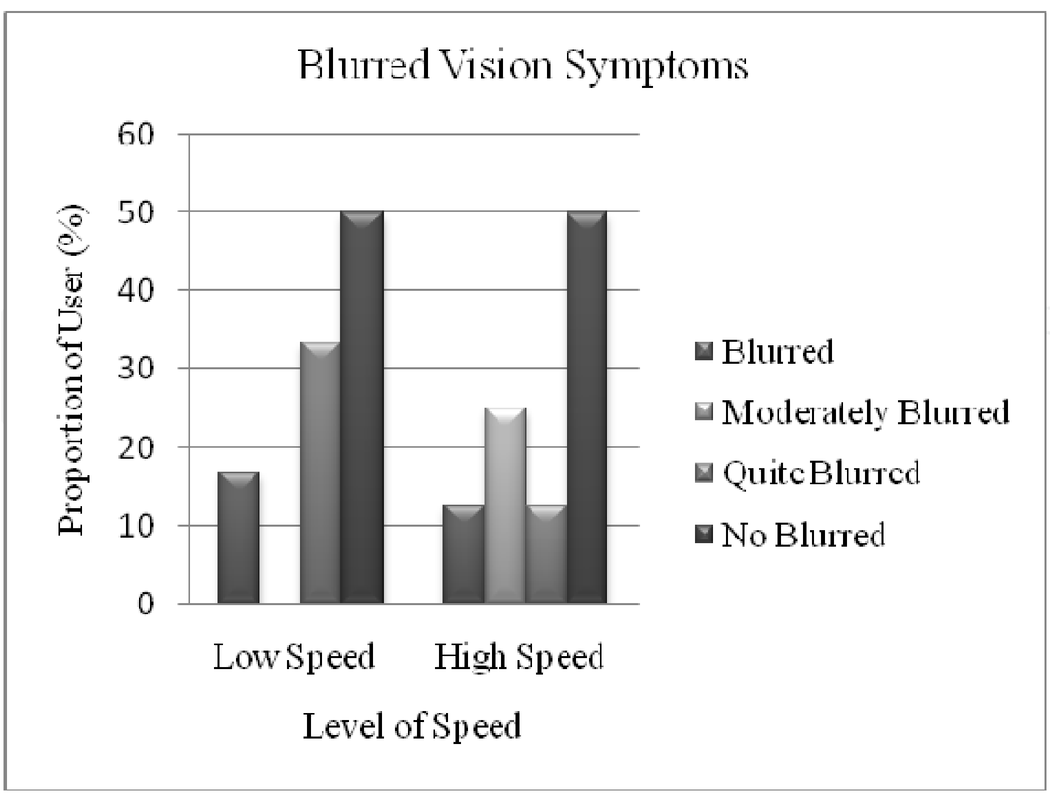
Different speeds of the virtual object motion in the VE were investigated. Statistical binomial test (Table 5) shows that users suffers from eyestrain, blurred vision and dry and irritated eyes when interacting with virtual objects at low and high speed of motion. This is because the eyes are trying to focus on the virtual object in motion which requires good coordination with the hand when performing task. Figures 6 (a), (b) and (c) shows the level of symptoms experienced by the users. It can be seen that the speed of virtual object motion needs to be considered as an attribute in designing of a VE. A higher speed of the virtual object motion is better than a lower speed. This is because at higher speeds there is no effect on users whether for eyestrain symptoms or dry and irritated eyes symptoms compared with lower speeds.

4.6 Analysis of the resolution of display

Many research have been conducted and have concluded that working with LCD screen is much more comfortable compared to working with CRT screens (Alstrom, et al, 1992; Saito, et al, 1993; Shieh,K.K., and Lin, C.C., 2000). This is contributed to the luminance contrast and limited viewing angle of LCD screens (Snyder, 1988). Additionally, the TFT-LCD screen seems to be the preferred technology by users for identifying letters on VDTs (Shieh, K.K. and Lin, C.C.,2000). In the current research, statistical binomial test (Table 6) have found that eyestrain and dry and irritated symptoms were experienced by users at three different resolution (high, medium and low resolution) whilst dry and irritated eyes incidence were experienced by users with the CRT screens at medium and low level of resolution only. This indicates that the resolution of display needs to be considered as one of the attributes in designing a VE.



(a)



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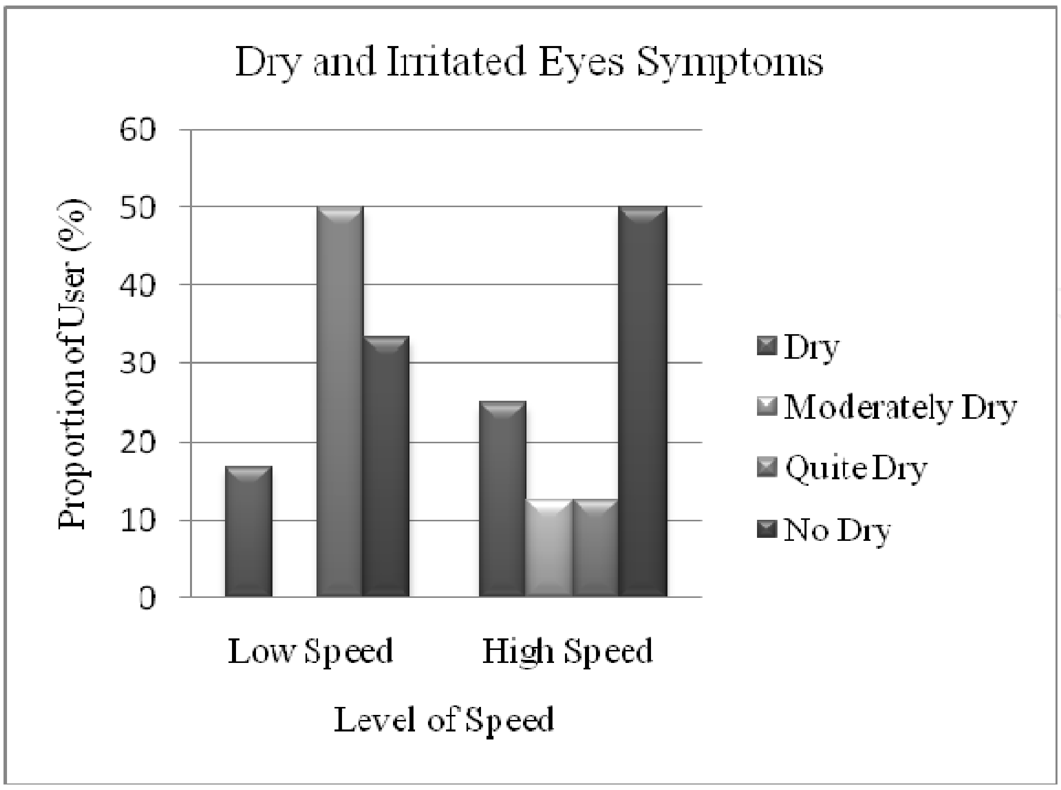
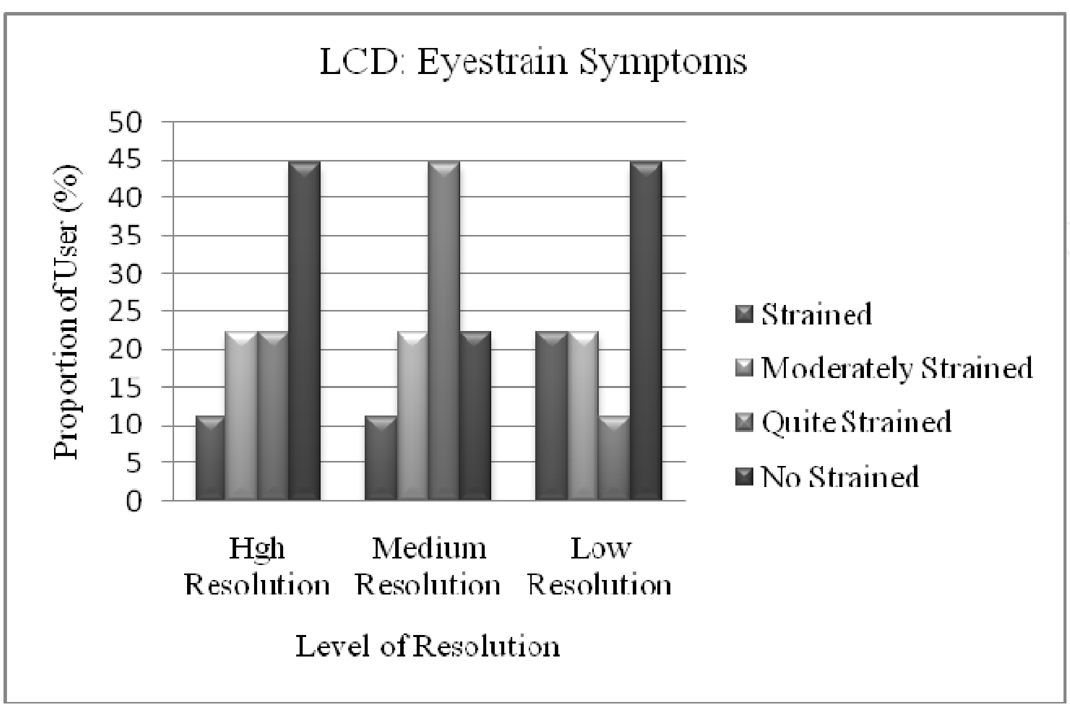


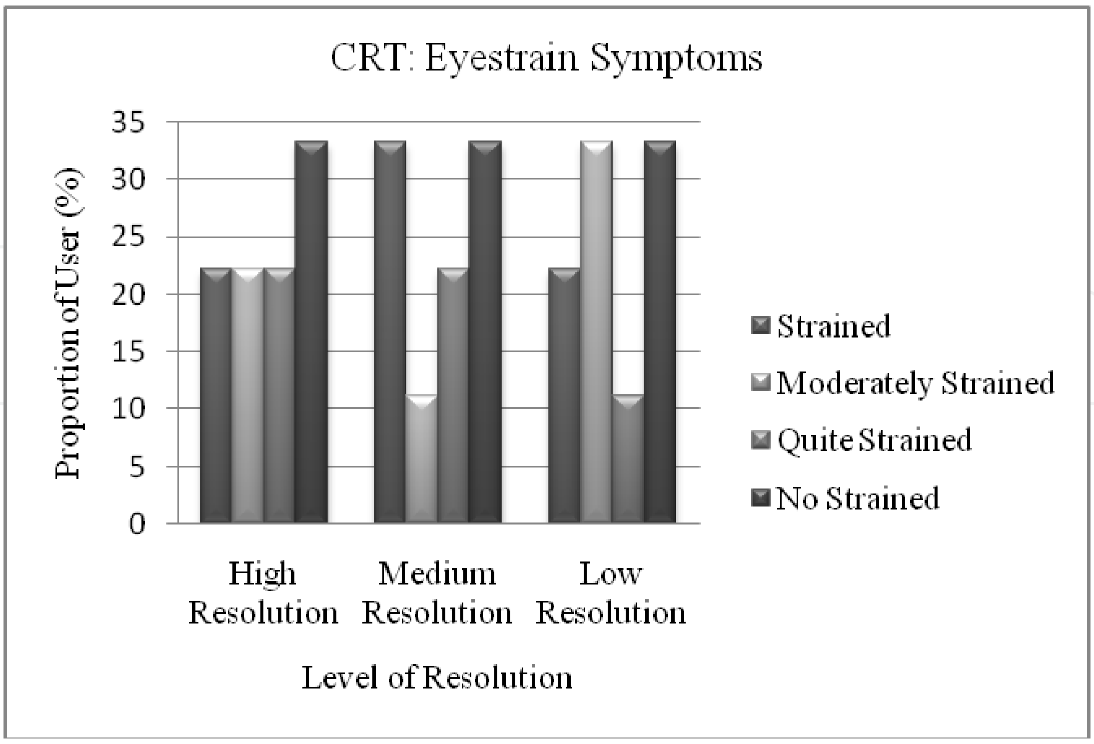
(c)

Fig. 6. (a) Level of eyestrain symptoms (b) Level of blurred vision symptoms (c) Level of dry and irritated eyes symptoms

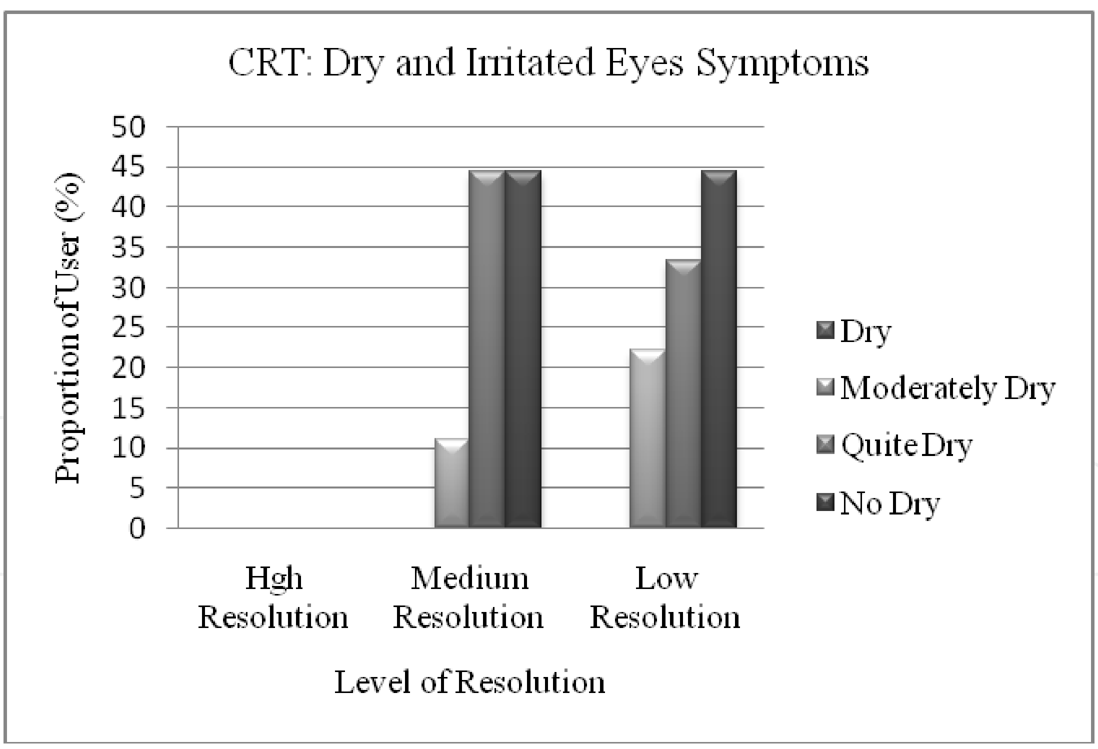
Figures 7 (a), (b) and (c) shows the level of eyes symptoms for different resolution. To avoid eyestrain symptoms, high and low resolutions are preferred for LCD screen because more than



(a)



(b)



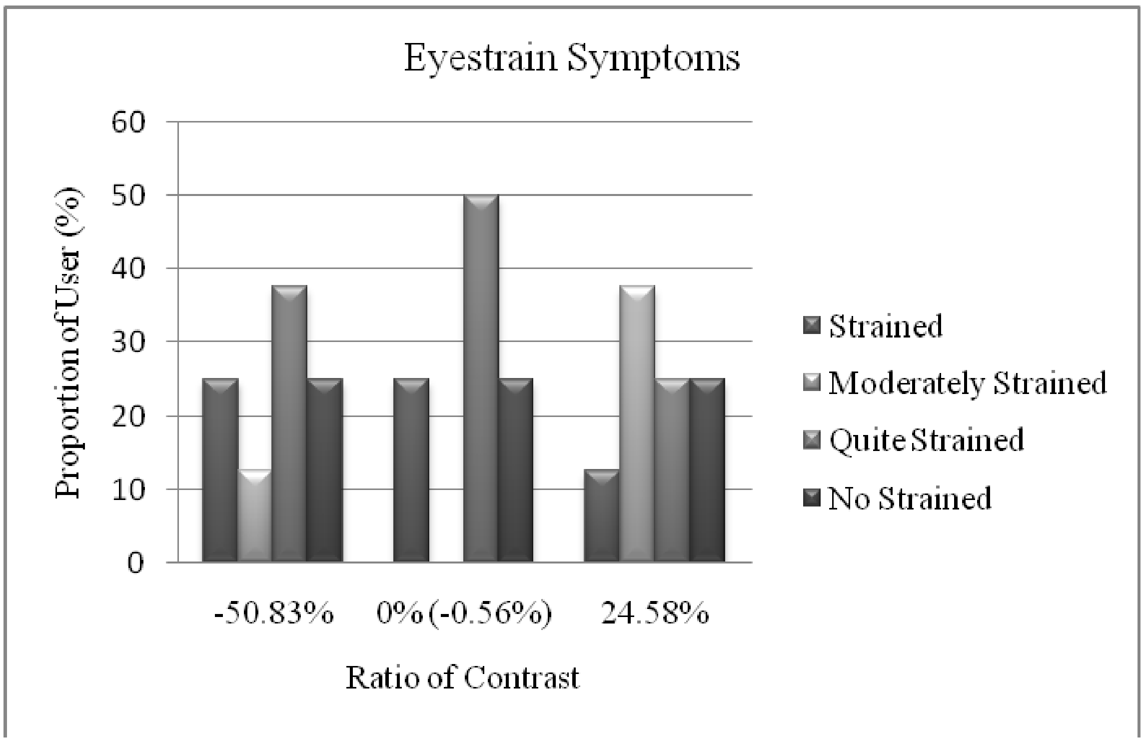
(c)

Fig. 7. (a) Level of eyestrain symptom on LCD (b) Level of eyestrain symptoms on CRT (c) Level of dry and irritated eyes symptoms on CRT

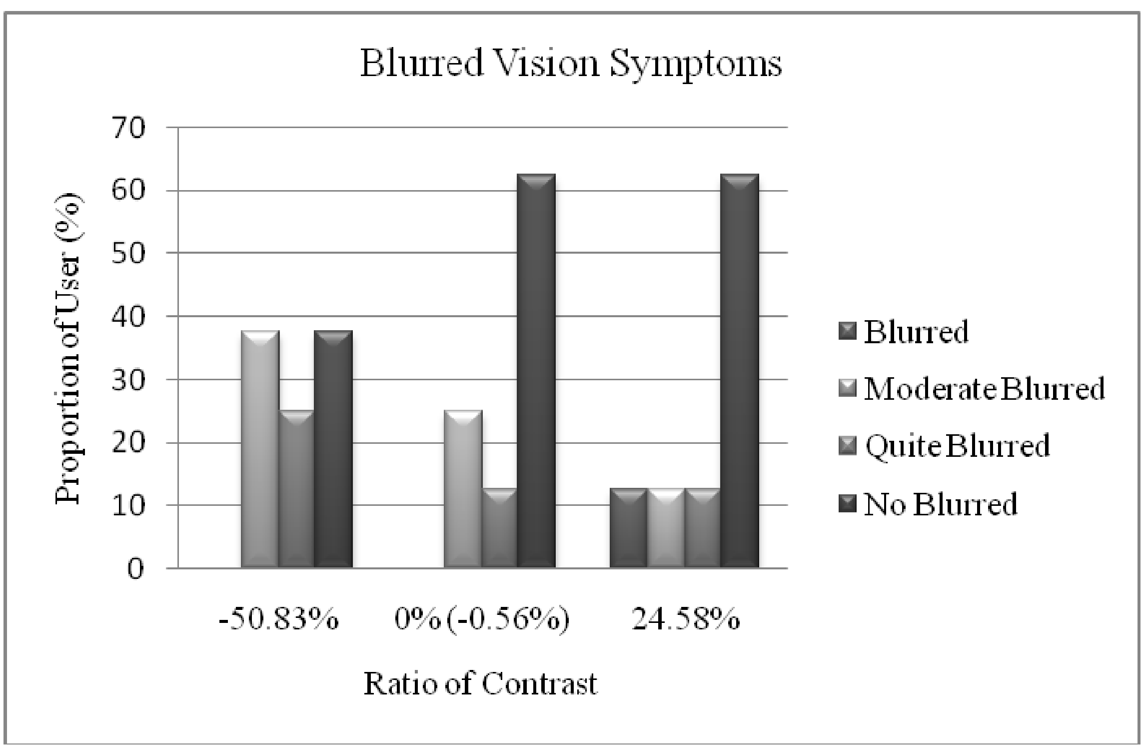
40 % of user did not experience any strain. But for CRT screen, all resolution level can be used because there were no incidence eyestrain symptoms or dry and irritated eyes symptoms.

4.7 Analysis of the contrast ratio between target and background

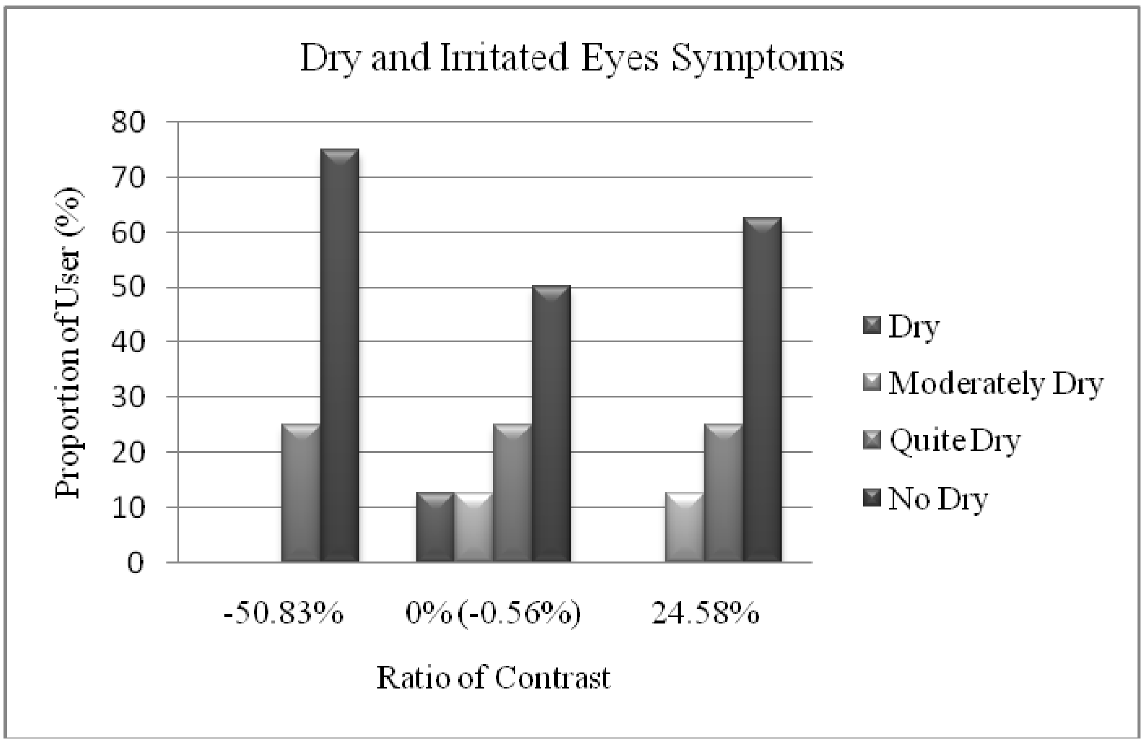
Figures 8 (a), (b) and (c) describes the level of incidence experienced by users for different contrast ratios. The result of statistical binomial test in Table 7 shows that eyestrain was



(a)



(b)



(c)

Fig. 8. (a) Level of eyestrain symptom (b) Level of blurred vision symptoms (c) Level of dry and irritated eyes symptoms

experienced by most users (75%) for all condition of contrast. While blurred vision was experienced by 63% of the users at -50.83% contrast ratios and dry and irritated eyes was experienced by 50% of the users at 0% (-0.56%) contrast ratios. This is due to the contrast condition affecting the ability of the eyes to distinguish the target from the background. Thus the contrast ratio should be considered as one of the attributes or variables in designing a virtual environment.

5. Conclusion

It can be concluded that:

1. The design of a virtual environment design is influenced by several attributes such as colour background, virtual lighting, field of view, flow rate, speed of virtual object, resolution of display and contrast ratio. These attributes significantly affect users particularly with eyestrain symptoms.
2. Blurred vision symptoms are significantly affected by several attributes of the VE design i.e. the red colour of the background, the field of view (FOV), the flow rate at ten seconds per piece (FR10), the speed of virtual object motion, and the contrast ratio at -50.83%.
3. Dry and irritated eyes symptoms are also significantly affected by several attributes of the VE design i.e. the virtual lighting at 10% and 100% levels of brightness, field of view (FOV) for all conditions, flow rate (FR) for all conditions, the speed of virtual motion for all speeds, the resolution of CRT screen at medium and low resolution and a contras ratio of 0%.

4. Virtual lighting at 100% level of brightness significantly affects visual symptoms, particularly light sensitivity symptoms of the users.

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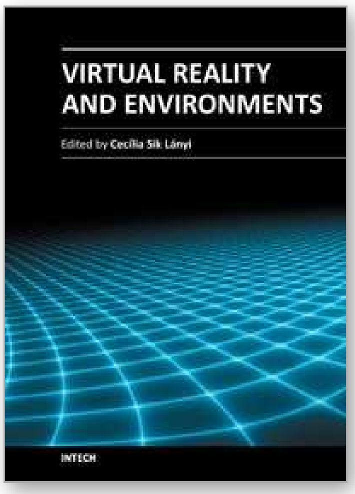

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Virtual Reality is clearly interdisciplinary research. It has, not only Information Technology importance but social, educational, economical importance too. It combines multiple disciplines for the development of virtual reality systems in which the user has the immersive feeling of being in the real world. Virtual reality has several applications in almost all fields of real life. The most typical fields for the application of virtual reality are health-care, engineering and game industry. This book may be a solid basis for the novice and advanced engineers who would like to develop user friendly Virtual Environments for education, rehabilitation and other applications of Virtual Reality. Our book provides a resource for wide variety of people including academicians, designers, developers, educators, engineers, practitioners, researchers, and graduate students.

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