iRIS-RT: Eye Fatigue and Reaction Time Detector

Kedsara Rakpongsiri[1]

ABSTRACT

The objective of this research is to develop an instrument to measure eye fatigue and reaction time for decision making. The data were automatically analyzed by the iRIS-RT program designed to measure the contraction or expansion of pupils by means of image processing in order to analyze changes of pupil diameters. The image processing technique is a set of images with continuous and different temporal intervals. The images are then transferred into a computer, stored and analyzed to obtain changes of pupil diameters. Pupil diameter of each image in each time interval is measured and frequency of blinking is detected and displayed on the computer screen in an attempt to analyze eye fatigue and to design the assessment of reaction time. The test program is designed with red, green and blue windows that randomly changes according to the set time in order to determine reaction to the colors and accuracy of decision to select the colors that correspond to those on the test program. The test results with the iRIS-RT program among 40 male and female volunteer participants aged between 18 and 35years reveal that the program is able to preliminarily measure and process eye fatigue. Furthermore, it is able to store and record personal results in the computer and Cloud media that are accessible via global online computer and internet systems. The results can be displayed on personal computers and other mobile devices. With regard to satisfaction of the participants with operations of the device, it is found that the satisfaction was at a high level, or 66.7%, and at the highest level, or 33.3%, on the overall efficiency of the device. From interviewing the experts after the construction of the device on its performance, attributes, size, safety, installation and result display, their satisfaction was at a high level.

Keywords: Eye Fatigue, Reaction Time, Computer Program

Manuscript received on August 2, 2017 ; revised on January 29, 2018.

Final manuscript received on May 14, 2018.

[1]The author is with Department of Physical Therapy, Faculty of Allied Health Science, Thammasat University (Rangsit campus), Pathumtani 12121, Thailand. Tel:02-986-9213-9 ext. 7208, 7256, Fax:02-516-5379, Email: krakpongsiri@gmail.com

1. INTRODUCTION AND OBJECTIVE

Visual perception is a function of the brain with our eyes being exposed to light. A complete visual perception system controls 90% of our daily activities and it is crucial for carrying out a job that involves eyesight. Eye fatigue is a symptom of tiredness to the eyes and the symptom may include redness, irritation, itchiness, reduced speed of image perception, blurriness, or double vision. Other physical effects may include arm ache, neck pain and others[1-3]. It may affect working efficiency, such as, working errors, increased accidents, and/or reduced job efficiency or quality[4-5]. The ability of human beings in response to stimuli depends on speed of reaction time which is an interval from the beginning of a stimulus to the start of the response. Reaction time relies on a travel of nervous currents from stimulus receptors to a conscious part of the brain through nervous cells and then sending back to concerned muscles. Reaction speed is derived from stimulation at sense organs, including hearing and visualization. Auditory stimulation takes the fastest reaction time, followed by visual stimulation. When the body works continuously for a long time, there may be fatigue, stress and reduced visual and decision-making abilities[6], resulting in decreased working efficiency and quality. If tiredness or risks of tiredness persist without stopping, it may have negative impacts on physical and emotional conditions[1-4], as well as visual competency because visual perception is closely related to eye fatigue. It is thus recommended that visual checkup be conducted annually. Fatigue prevention in risk groups should be seriously taken into consideration by visual rest, frequent blinking or seeing opticians when necessary[1-2].

Nowadays, computer technology has been well advanced and played a crucial role in satisfying human needs, particularly in applying the technology to business, industry, medicine and education. Aspects of this application are mainly in the forms of data storage, retrieval and processing, work design, and control of devices and equipment. This technology can be integrated into health-oriented devices for primary healthcare. It is thus interesting to develop a device for eye care that is able to detect eye fatigue and reaction time for decision making by oneself with ease, convenience and safety. This endeavor is in line with the main research strategy of Thailand regarding health promotion, prevention of new outbreaks, medical treatment, and physical and psychological rehabilitation by developing the device that is able to automatically analyze the data with a computer program. Moreover, it is able to record the data and results on the Cloud media that can be accessed via online computer and internet systems anywhere in the world. The results can be displayed on personal computers and other mobile devices, so that awareness on eye care, prevention and reduction of risk factors is raised in an attempt to reduce disease incidents, treatment time and expenses, and economic crisis. It is also applicable to provide eye care recommendations to others in order to improve the quality of life of social and community members.

2. CONSEPTUAL FRAMEWORK

Eye fatigue is a symptom after using the eyes to focus on something for a long time, causing abnormal visualization, such as, blurriness, dryness, irritation, sensibility to light, unclear vision or double vision. An important cause of eye fatigue is the ciliary muscle of the eyes being contracted or expanded for a long period of time while intentionally focusing on a particular object. The object may be very tiny or in an unclear condition, requiring a stare to focus it onto the retinas. It is also found that eye fatigue is related to a long period of work. In some cases, it may be accompanied by dizziness and affect other physical systems, such as, pains on the arms and neck. Furthermore, it may have negative impacts on job performance, for instance, increased errors or accidents, lower productivity, and reduced job quality and efficiency[7-9]. Previous studies have confirmed that eye fatigue lowers visibility and has negative effects on working efficiency. Sheedy et al.(1994)[7] revealed that work requiring eyesight causes health problems of workers, particularly when staring at an object at a close range. In such a circumstance, eyeballs are reclined together in order to focus the image onto the retinas, leading to abnormality of eyesight, such as, eye fatigue, irritation, blurriness, slow focus, and/or temporary double vision. Studies on computer workers reveal that a large number of them have eye problems together with other muscular problems and these problems are directly related to length of working time in each day[8, 9-12].

Human capability of responding to stimuli depends on speed of reaction time, starting from receiving a signal to move to working or moving until the obligation is complete. The times include reaction time, movement time and response time. Thus, reaction time refers to the total interval from stimulation or the appearance of a stimulus to physical movement until completion. Speed of reaction time is a consequence of being stimulated at sense organs. It is found that auditory stimulation takes the shortest reaction time, or fastest response, followed by visual stimulation, pain, taste, smell, and touch respectively. Additionally, other factors, such as age and gender, affect reaction time. It is revealed that reaction time is longer in children than in adolescents. With increasing ages, reaction time gradually lowers but increases or stays longer in old age. Reaction time in males is shorter than in females. Intensity of auditory and visual stimulation lowers reaction time. However, too much stimulation may lengthen reaction time[5]. From the above-mentioned data, psychological changes as well as physical fatigue due to a long period of working time can negatively affect job performance, lower movement efficiency, slow job performance perception and precision, increase performance mistakes, reduce the ability of muscular response, lengthen decision-making time, and unusually lengthen reaction time. Consequently, exposing to such circumstances for a long period of time may lead to negative physical and psychological effects[8-10].

3. BACKGROUND AND RELATED WORK

An accepted tool to test eye fatigue among scientists and researchers is Flicker Test or Flicker Instrument. The operation principle of the tool was designed to be compatible with the principle of Critical Fusion Frequency (CFF). That is, there is a speed control of a segment disk by increasing or decreasing frequency signals of electrical current to about 40-50 Hz, bringing about the flicker of the bulb or the orange spot on the screen, or without flicker. Frequency of the segment disk movement corresponds with frequency of human brain in the area of visual perception. Frequency of the alternate color movement of flicker makes them become one color and this image is sent to the brain in the form of electrical waves. Normal CFF values are between 30 and 40 cycle/second[2-3]. If a participant is in a normal physical condition, his body can respond quickly. If he is tired, the response is slower. Studies on implementing CFF to assess eye fatigue have been numerous. Most studies in Thailand focus on the implementation of CFF or CFF with other tests. For instance, there has been an implementation of CFF in conjunction with an eye competency test[1] or with a decision-making ability measurement after carrying out physical activities at different levels of intensity[7]. Nevertheless, there have been reports on restrictions of CFF. It is found that there are conflicting reports on standard values of CFF at the range of 30-40 CPS. However, this standard may not be applicable to everyone, because there are other factors that change responses, such as, freshness from rest, excitement, panic, sound volume of stimulation, and emotional states of a participant. These factors can quickly fluctuate CFF values of individuals[11-12]. Bartley and Chute summarized that if the body is deprived of rest, CFF values may not be in line with actual conditions of an individual. Moreover, flickering of the screen may cause errors of the brain in reporting CFF values[2-4]. There have been research reports overseas using physical indices as indicators of eye fatigue[12-14], such as, internal and external muscles of the eyes, periodic stare and vergence, or pupil size. For instance, when eye muscles move slowly, they may indicate fatigue or faster blinking may indicate more eye fatigue. Pupil size can be an indicator to assess eye fatigue. When light changes, pupils contract or expand with pupil muscles functioning to adapt pupil sizes to properly allow light into the retinas[6]. This finding is in line with a study utilizing a questionnaire together with records of blinking and speed of pupil contraction and expansion by photographing changes of pupils while working. The data were analyzed by the image processing program. The study focuses on eye fatigue due to watching a movie on LCD screen in comparison with PDP screen. It is found that blinking rate increased and speed of pupil contraction or expansion decreased when watching the LCD screen. It was concluded that watching an LCD screen might cause more eye fatigue than watching a PDP screen[12]. It is also revealed that watching a 3D movie for 30 minutes makes pupil size smaller than watching a 2D movie and watching at a longer distance expands pupil size[14].

The image processing technique is a processing of images and calculating the results electronically. There are various methods of calculation, for instance, calculating pixel colors or different areas to obtain patterns, textures or shapes. Sources of the images may be from a digital camera, scanning or digital media. The images are then undergone a process to derive new images, such as, blurred or emboss images. Edge detector is a science that is beneficial to and can be applied in various fields, such as, medicine, security, head count, or movement detection of objects in an image. Digital image processing is a field involving in techniques and algorithms used for processing digital images, covering video signals or moving picture, which are sets of still pictures, called frames, continuously rolling according to a set timeframe[6, 8, 11-14] From the above literature review, it is revealed that many types of jobs are a risk factor for eye fatigue that may affect job performance efficiency as well as physical and psychological health. Current technological changes have been progressing rapidly, raising more awareness on healthy lifestyle. Therefore, health-related devices have been invented and designed to enable users to realize their well-being and use as a guideline for personal healthcare. Nonetheless, devices for detecting eye fatigue by oneself have been few and there has not been any device to clearly confirm the symptom. The existing ones, however, are expensive and complicated to use. It is thus interesting to develop a device for measuring eye fatigue and reaction time for decision making by oneself, which is easy, convenient, accurate and safe to use. The analysis results are automatically conducted by a computer program through the image processing method. The results can be displayed and recorded onto the Cloud media that can be accessed via online computer and internet networks.

4. METHODOLOGY

Communication and information transfer are easily accessible nowadays. Both computers and mobile devices have been widely used in today's society. The concept of developing a device for measuring eye fatigue was initiated, based on the standard prototype model, Flicker Test or Flicker Instrument, which is widely acceptable among scientists and researchers. It is incorporated with the principles of changes of pupil muscles and frequency of blinking when working for a long time or when eye fatigue occurs. Changes of pupils are photographed continuously and analyzed by the image processing technique. Eye fatigue brings about poor visibility, slow decision making and unusually long reaction time. The choice reaction time response method is used to measure reaction time in this study. Results are automatic, enabling users to realize the level of fatigue or decision-making ability. The data were collected and stored onto a personal computer as well as the Cloud media, so that the results can be displayed on computers and mobile devices.

4.1 Construction steps

1. Designing the device to detect the contraction or expansion of pupils by taking images and analyzing changes of pupil size through the image processing method. The images are taken at different time intervals and continuously. The images include video signals or moving pictures, consisting of a set of still images, called frames, projecting chronologically. The data are transferred to a computer, stored and analyzed to display changes of pupils. The images of the pupils are measured diametrically at different time intervals. Furthermore, frequency of blinking is detected and displayed on the computer screen in order to analyze eye fatigue (Fig.1).
2. Designing the measurement of reaction time in the form of choice reaction time. The test is designed by using color windows consisting of red, green and blue. Color changes are randomly set at a specified time in order to determine reaction time toward a stimulating color and accuracy of decision making (Fig.2).

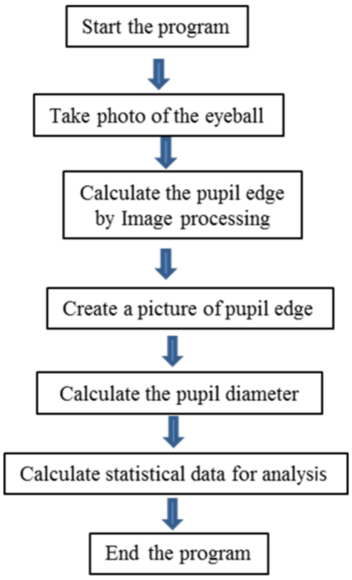


Fig.1: *Diagram of a computer program for detecting pupils changes.*

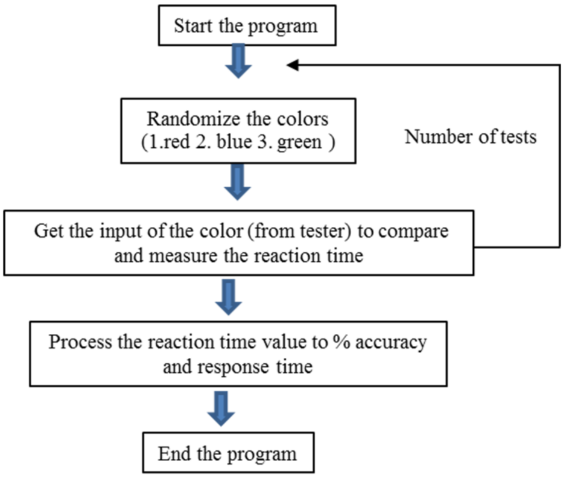


Fig.2: *Diagram of a computer program for measuring the reaction time.*

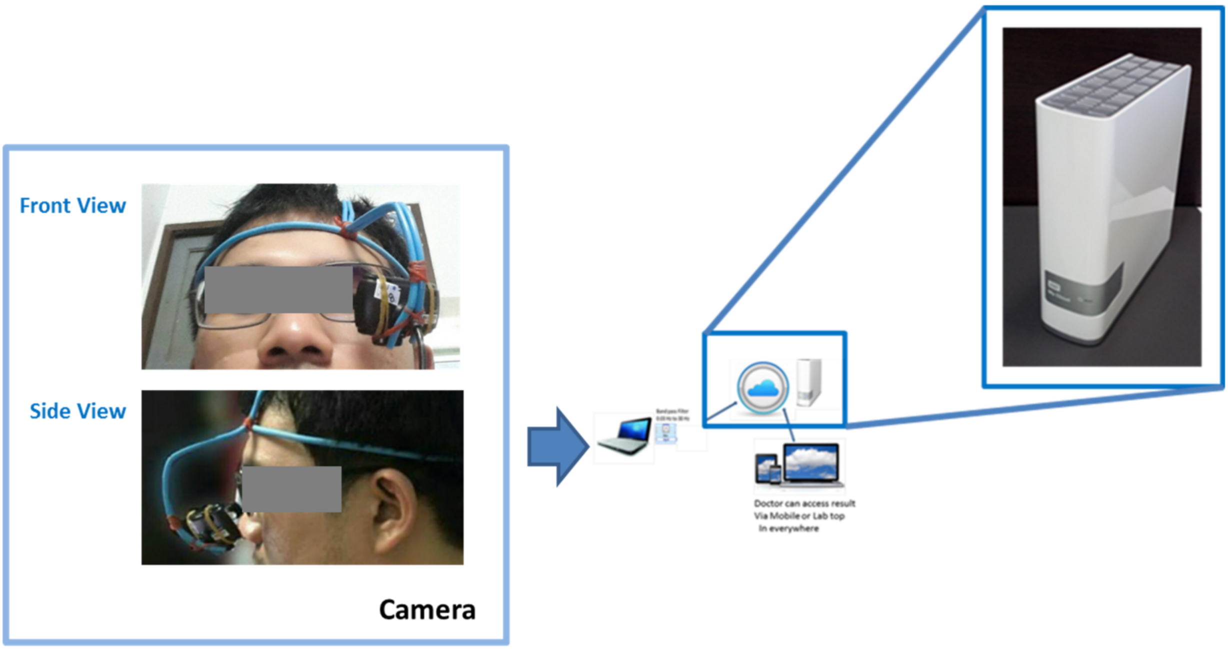
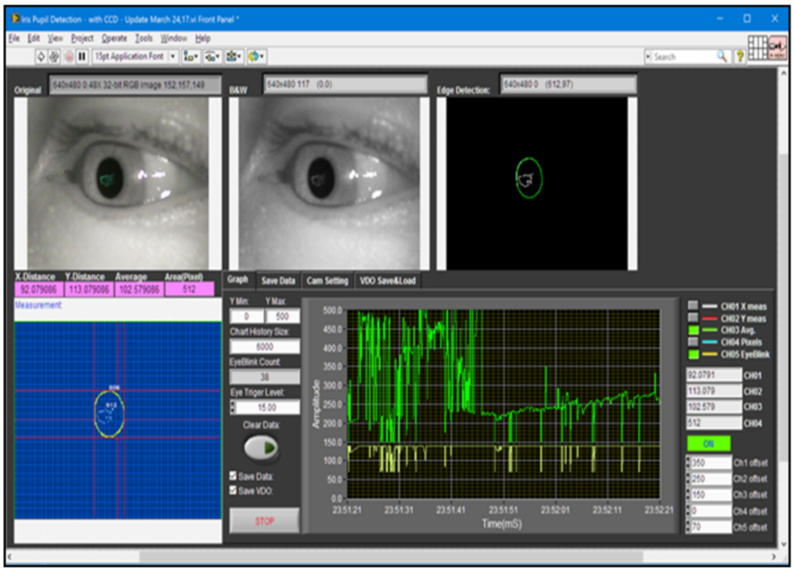
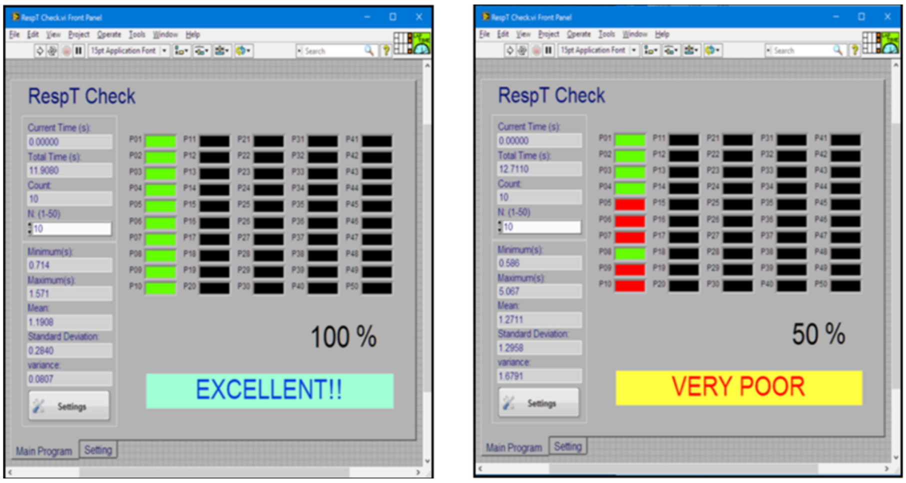


Fig.3: *The iRIS-RT, Eye fatigue evaluation and reaction time responses system for displaying a personal report through an online computer network.*



(a)



(b)

Fig.4: *The example test image of the "iRIS-RT" system. a. Measurement and recording of pupillary diameter changes and number of blinking. b. Measurement of reaction time and accuracy percentage of color test.*

0	1	2	3	4	5	6	7	8	9	10
No eye pain or eye irritation or eye irritation.	Eye or eye irritation or slight eye irritation. no suffering, no worries about pain right now.			Eye or eye irritation or moderate eye irritation. Feeling suffering from moderate pain. There is not much concern, there are feelings that can tolerate.			Eye or eye irritation or very irritating to the eyes. Feeling suffering from a lot of pain. Cause a lot of anxiety and can not sleep.			Eye pain or eye irritation or severe eye irritation can not stand.

Fig.5: *The Visual analog scale, VAS.*

5. DESIGN RESULTS

The iRIS-RT, Eye fatigue evaluation and reaction time responses system for displaying a personal report through an online computer network shows in figure 3.

Program to measure contraction or expansion of pupils

An infrared video camera is used to detect the contraction or expansion of the pupils. The eye image signals are then transferred to the processing system. The images are adjusted for suitability and processed to determine the edges of the pupils. After that, diameters of the pupils are measured along the x and y axes. Furthermore, blinking is detected in order to display pupil size at different time intervals and number of blinking to be incorporated into the fatigue analysis. The data are recorded onto the computer and Cloud media by utilizing the LabView Program, which was invented by the National Instrument Company for use in computer engineering work (Fig.4a).

Program to measure reaction time for decision making

The choice reaction time is employed to measure reaction time for decision making by using color windows consisting of red, green and blue. Color changes are set according to specified times. Participants are required to press the color they see in order to determine their reaction time to the color and accuracy of their decisions. Values of their reaction times and accuracy of color choice are processed by the LabView Program to indicate a preliminary level of fatigue (Fig.4b).

6. TESTING AND EVALUATION

The participants were seated comfortably on the chairs and the computer screens were adjusted at the eye level. The cameras to take images of pupil diameters were equipped for the participants. The program was turned on to measure and record changes of the diameters. Standard circles were calibrated with their diameters the same sizes as those of human pupils, approximately 4 millimeters (about one minute). Testing for eye fatigue started by having the participants stare at still images on the screens for 30 minutes. The participants were then tested for their reaction times by turning on the reaction time measurement program. The program measured and recorded reaction times and percentage of decision-making accuracy in selecting the right colors from the screens. The post-test on eye fatigue by Visual analog scale (VAS) was conducted (Fig.5).

7. DISCUSSION AND CONCLUSION

Our system is the first idea to combine the eye fatigue measurement and reaction time test with the automatic report and keep the results on cloud system. The reaction time for decision making with factors of time response, multi colors and accuracy of decision should be the first idea for the measurement and the test. This study focuses on the construction of a device to measure eye fatigue and reaction time for decision making. The data were automatically analyzed by the iRIS-RT program by measuring changes of pupil diameters and reaction time. The device can be used in conjunction with personal computers and other mobile devices, making it portable and user-friendly. It is safe because it is designed to be used with a camera without directly touching the eyes of users. Moreover, it is used via computer USB ports. Additionally, it is covered with electrical insulators, making it safe from high voltage electrical current. The data and results can be stored and recorded on the Cloud media through online and internet systems. Testing eye fatigue and reaction time was administered with 40 healthy male and female volunteer participants aged between 18 and 35 years. The video cameras continuously took images of their eyes staring at the same still image on the screen for 30 minutes. The program then measured diameters of the pupils, recorded changes of the diameters according to time intervals, and displayed number of blinking as well. The test results on female participants reveal that the means of the diameters before and after the test were 3.38 millimeters and 4.00 millimeters respectively (Table 1). The mean of changes before and after the test was 0.62 millimeters and the average blinks were 248 times. When testing for reaction time for decision making, it is found that the mean was 1.08 seconds and the percentage of decision accuracy was 66. The average scores from eye fatigue measurement (VAS) were 5.25. The test results on male participants reveal that the means of the diameters before and after the test were 3.22 millimeters and 4.00 millimeters respectively (Table 2). The mean of changes before and after the test was 0.77 millimeters and the average blinks were 246.5 times. When testing for reaction time for decision making, it is found that the mean was 1.08 seconds and the percentage of decision accuracy was 64.5. The average scores from eye fatigue measurement (VAS) were 5.15. The device with the iRIS-RT program used in this investigation is based on the principle in the study of Gonzalez and Wood, reporting that measuring pupil size is another indicator of eye fatigue, since when the light changes, pupils will contract or expand. The iris muscle is responsible for adjusting the pupils to allow an appropriate amount of light into the retinas[6]. The results of this test also reveal that diameters of the pupils increased in both male and female participants. Previous studies found that measuring pupil size is another indicator of eye fatigue. When the light changes, pupil size will contract or expand. Pupil muscles are in charge of adjusting pupil size to allow just enough light into the retinas. Fundamentally, muscle contraction or expansion is a response

Table 1: *The pupillary diameter change (mm), number of blinking, reaction time value for decision and the VAS score for 20-year-old female volunteers aged 18-35 years.*

No	Age	pupillary diameter change (mm),			number of blinking	reaction time value for decision		VAS score
		Before	After	Change values before and after testing		Average time (msec.)	Color accuracy percentage selection	
1	18	3.19	3.37	0.18	290	1.17	80	5
2	20	3.09	3.47	0.38	220	0.9	70	5
3	22	3.80	4.20	0.4	210	1.14	50	6
4	19	3.27	3.91	0.64	220	1.11	50	6
5	25	3.40	3.97	0.57	230	1.15	60	6
6	30	3.25	3.96	0.71	210	0.98	80	5
7	33	3.34	4.66	1.32	245	1.2	50	6
8	35	3.40	3.99	0.59	270	1.13	80	5
9	34	3.40	3.76	0.36	290	0.97	70	4
10	35	3.60	3.89	0.29	280	1.19	70	4
11	19	3.29	4.37	1.08	210	1.17	50	6
12	22	3.09	3.47	0.38	220	0.9	70	5
13	20	3.80	4.20	0.4	210	1.14	50	6
14	29	3.07	3.91	0.84	220	1.11	50	6
15	35	3.40	3.97	0.57	290	0.95	80	4
16	30	3.15	4.16	1.01	210	1.28	80	6
17	23	3.34	4.66	1.32	245	1.2	60	6
18	25	3.40	3.99	0.59	300	0.93	80	4
19	34	3.60	4.16	0.56	290	1.17	60	6
20	35	3.65	3.90	0.25	300	0.89	80	4
Mean		**3.38**	**4.00**	**0.62**	**248.00**	**1.08**	**66.00**	**5.25**

Table 2: *The pupillary diameter change (mm), number of blinking, reaction time value for decision and the VAS score for 20-year-old male volunteers aged 18-35 years.*

No	Age	pupillary diameter change (mm),			number of blinking	reaction time value for decision		VAS score
		Before	After	Change values before and after testing		Average time (msec.)	Color accuracy percentage selection	
1	28	3.19	4.37	1.18	210	1.17	60	6
2	30	3.09	3.47	0.38	290	0.95	70	4
3	32	3.10	3.90	0.8	210	1.14	50	6
4	19	3.27	3.91	0.64	220	1.11	50	6
5	25	3.10	3.97	0.87	230	1.15	60	5
6	30	3.15	3.96	0.81	210	1.28	80	5
7	23	3.14	4.60	1.46	210	1.20	50	6
8	35	3.30	3.90	0.6	270	1.13	60	5
9	34	3.10	3.76	0.66	300	0.95	80	4
10	25	3.30	3.89	0.59	300	0.90	70	4
11	20	3.19	3.37	0.18	280	0.97	80	4
12	20	3.09	4.47	1.38	210	1.19	70	6
13	22	3.80	4.25	0.45	210	1.14	50	6
14	29	3.17	3.91	0.74	220	1.11	50	6
15	25	3.10	3.97	0.87	230	1.15	60	6
16	20	3.25	3.96	0.71	270	0.98	80	4
17	33	3.34	4.66	1.32	220	1.2	50	6
18	35	3.10	3.99	0.89	270	1.13	80	6
19	34	3.10	3.76	0.66	290	0.97	70	4
20	35	3.60	3.90	0.3	280	0.80	70	4
Mean		**3.22**	**4.00**	**0.77**	**246.50**	**1.08**	**64.50**	**5.15**

to eye fatigue[6, 15]. In general, an individual blinks 15-20 times a minute or averaging 22 times per minute. However, when eye muscles work harder during reading or watching images for a long period of time, the muscles will become tense when forced to work continuously and blinking will reduce[1-2, 10, 12]. In this investigation, eye fatigue was found among the participants because they were obliged to stare at the still image continuously for 30 minutes. Thus, during normal circumstances, the average blinks are 22 times per minute. The total blinks should have been 660 per thirty minutes. Nevertheless, the number of blinks was found to reduce to 248 times in the female participants and 246.5 times in the male participants. They encountered eye fatigue, so their blinks reduced accordingly.

The average reaction time among the participants was found to be higher than the criteria when compared with the reaction time criteria for individuals with different ages by Phenchan and Anek[16]. It can be stated that reaction time of the participants after the test was in the slow reaction category for both genders. Furthermore, color selection errors were found to be 34% in females and 35.5% in males. It is thus likely that they suffered eye fatigue. This finding is in line with eye fatigue measurement scores by using the visual analog scale. It is revealed that the scores of the female participants were 5.25 and those of the male participants were 5.15. This means that there was eye pain or irritation at the moderate level. They felt painful at the moderate level and there was not much anxiety and they were able to tolerate it (Fig.5). This finding is in accordance with previous studies. It is found that when the body was obliged to work for a long period of time, there might be physical fatigue and stress, lower visibility and reduced decision-making ability[3-4, 12-13]. Job performance efficiency and quality might be reduced. If the condition persisted, there might be negative impact on physical and psychological health[17]. However, changes of pupil size due to work may not be solely dependent on a long duration of work. Other factors include lighting, blinking or emotional states. Therefore, to reduce eye fatigue due to work, it is recommended that a workplace be suitably designed regarding lighting or distance between the eyes and the images. These conditions may reduce the eye fatigue phenomenon[1-2, 11, 12].

With regard to satisfaction with the device of the participants, it is revealed that they were satisfied with the following attributes of the device: ease of use, portability, size and weight, safety, application with online media on a daily basis, and overall satisfaction with the device. With reference to the satisfaction results in Table 3, it is summarized that 33.3% of the participants were satisfied at the highest level and 66.7% were at the high level. The results from interviewing the experts in designing the device in Table 4 are summarized as follows. Utilizing the device is convenient because users are able to operate the device like they use their computers. They simply click at the icons in the program on the computer screen and the device can be operated. The device is small and portable as well as compatible with an ordinary computer. The data can be retrieved on personal computers and other mobile devices through online computer and internet systems on the Cloud media. It is also safe because the device was designed by using a camera without directly touching the eyes of users. The device is used via USB ports with electrical insulator to prevent danger from high voltage electrical current. The program is easy to operate, analyze, record into a data file, and retrieve to display the results. Additionally, it is able to analyze the values of eye fatigue on a rudimentary basis. Its overall efficiency on operation, aspects, size, safety, installation, and result display program is at a high level. From this investigation, it is possible to further develop the device in both software and hardware terms, making it smaller or designing it like eye glasses for ease of use. It can be further developed in real time on smart phones for the general public to use while carrying out daily activities like working or exercising. Moreover, collaboration with medical personnel should be sought to improve the analysis program and to apply for further research with a larger target group.

Table 3: *The satisfaction percentage with the device of the 40 participants.*

	Percentage (%)	
	much	**most**
1.Comfortable of using	66.7	33.3
2.Comfortable of portability or mobility	33.3	66.7
3.Safety		100
4.Performance	66.7	33.3
5.Apply online on a daily lifestyle.		100
6.Overall satisfaction.	66.7	33.3

ACKNOWLEDGEMENT

The author gratefully acknowledge the financial support provided by Thammasat University Research Fund under the TU Innovative Scholar, 2016.

References

[1] S.H. Bartley, E. Chute, "*Fatigue and impairment in man*," USA: Mc.Graw-Hill Book Company, pp.156-162, 1947.

[2] B. Clayton, V. Seema, K. Ashbala, et al., "Computer vision syndrome: a review survey," *Ophthalmol*, vol.50, pp.253-62, 2005.

Table 4: *The interviewing of the 3 experts in designing the device iRIS-RT.*

Question	Answer		
	Expert 1	Expert 2	Expert 3
1 Using of the device is convenient or not ? and how?	Yes, it is convenient because users can use the equipment like using a personal computer, and simply click the icon in the program.	Yes, it is convenient because user is familiar with the computer, and the program is not complicate.	Yes, the system is easy and convenient of using.
2 To carry or move the device easy or not ? and how?	Yes, because the system is portable and easy to carry around for using any place.	Yes, the device is small and portable as well as compatible with an ordinary computer	Yes, it is convenient and portable, and works with a general computers
3 The device is safe or not ? and how ?	Yes, the device is used via USB ports with electrical insulator to prevent danger from high voltage electrical current.	Yes, it is good design of safety concept.	Yes, It is safe because the device was designed by using a camera without directly touching the eyes of users.
4 Using the program of device is convenient or not ? and how?	The program is easy to operate, analyze, record into a data file, and retrieve to display the results.	Yes, it is easy to learn of using the program.	Yes, it is not difficult of running the functional programs.
5 What about the overall performance of the device ?	Overall performance rating is good.	Equipment's overall performance is good.	Good for overall performance.

[3] M.J. Dainoff, A. Happ and P. Crane, "Visual fatigue and occupational stress in VDT operators," *Human Factors*, vol 23, no.4, pp.421-438, 1981.

[4] J.P. De Groot and A. Kamphuis, "Eye strain in VDU users : physical correlates and Long-term effects," *Human Factors*, vol.24, no.4, pp.409-413, 1983.

[5] D.M. Eagleman, "How does the timing of neural signals map onto the timing of perception?", In: *Problems of space and time in perception and action*, (Nijhawan R, ed). Cambridge, UK: Cambridge UP, 2005.

[6] R.C. Gonzales and R.E. Woods, *Digital Image Processing*, 3rd. ed. Pearson Education, Inc, 2008.

[7] J.E. Sheedy, "Vision and work" In: *Occupational health and safety*, Edited by Ladou J. 2nd ed. USA: National safety council, 1994.

[8] P.V. Karpovich, *Physiology of Muscular Activity*, W.B.: Suanders Company, Philadelphia, 1962.

[9] R. Magaret, *The Dynamic of Motor Skill Acquistion*, Englewood Cliffs: Prentic-Hall, Inc, Saint Louis, 1972.

[10] L.G. Shava, *Essential of Exercise Physiology*, Surjert Publication, Minnessota, 1982.

[11] E.C. Lee, K.R. Park, M. Whang and K.H. Min, "Measuring the degree of eyestrain caused by watching LCD and PDP devices", *International Journal of Industrial Ergonomics*, vol.39, pp.798-806, 2009.

[12] T.H. Laubli, W. Hunting and E. Grandjean, "Postural and visual loads at VDT workplaces II lighting conditions and visual impairment," *Ergonomics*, vol. 24, no.12, pp.933-944, 1981.

[13] E.C. Lee, K.R. Park, M. Whang and K.H. Min, "Measuring the degree of eyestrain caused by watching LCD and PDP devices," *International Journal of Industrial Ergonomics*, vol.39, pp.798-806, 2009.

[14] E.C. Lee, J.W. Lee, and K.R. Park. "Experimental investigations of pupil accommodation factors," *LENS*, vol.52, no.9, pp.6478-6485, 2011.

[15] B.B. Ritchie and J.J. Woods, "Changes in Muscle Contractile Properties and Neural Control During Human Muscular Fatigue," *Muscle & Nerve*, vol.7, no.9, pp.691-699, 1984.

[16] P. Srisooksawat, and A. Sootmongkol, "Reaction Time of Men and Women at Difference Age Group," *Journal of Education*, vol.15, no.1, pp.57-72, 2013.

[17] A.M. Rossignal, et al., "Video display terminals use and reported health symptoms among Massachusetts Clerical worker," *Journal of Occupational Medicine*, vol.29, no.2, pp.112 -118, 1987.

Kedsara Rakpongsiri is an associated professor in department of Physical Therapy, Faculty of Allied Health Science, Thammasat University. She received the BS degree in Physical Therapy from Chiang-Mai University in 1990, and the MS in Exercise Physiology from Mahidol University, in 1998, and the PhD degree in Physiology from Chulalongkorn University, in 2008. Her research interests include an application of physiological signal and technology for health innovation, Exercise & work physiology and Pediatrics physiotherapy.