Published online: 20 July 2018

Long Term Blue Light Exposure Effect on Macular Pigment Optical Density (MPOD)

Wilasinee Buddha

Email: sweet_por@hotmail.com

Master of Science in Anti-Aging and Regenerative Science

School of Anti-Aging and Regenerative Medicine

Mae Fah Luang University

Werner Kurotschka, M. D., Ph. D.

Email: drkuro@aol.com

School of Anti-Aging and Regenerative Medicine

Mae Fah Luang University

Abstract

The study on Long Term Blue Light Exposure Effect on Macular Pigment Optical Density (MPOD) was a survey research with the objective to compare macular pigment optical density level (MPOD) between infrequent/low-usage persons ($\leq$ 5 hours/day) and frequent/high-usage persons ($\geq$ 9 hours/day) that use electronic devices. The sample group was consisted of 162 male and female subjects. The subjects were classified into 3 groups, e.g., the low usage with time spent on electronic device $\leq$ 5 hours/day, the moderate usage with time spent 5.1-8.9 hours/day, and the high usage with time spent $\geq$ 9 hours/day. Subjects were required to complete personal data record form and capture measurement of MPOD level by using Macular Pigment Optical Densitometer (M-POD). The result showed that the difference in MPOD levels in each usage category were statistically significant at $p < 0.05$. The mean of MPOD levels of the Low Usage was significantly higher than that of the Moderate Usage (0.68±0.14 and 0.53±0.11, $p < 0.05$ respectively). The mean of MPOD levels of the Moderate Usage was significantly higher than that of the High Usage (0.53±0.11 and 0.38±0.10; $p < 0.05$ respectively). And the mean of MPOD levels of the Low Usage was also significantly higher than that of the High Usage (0.68±0.14 and 0.38±0.10, $p < 0.05$ respectively). The result from comparing MPOD levels between the low-usage persons ($\leq$ 5

hours/day) and the high-usage persons ($\geq$ 9 hours/day) showed that the low-usage persons had higher MPOD level than that of the high-usage persons. There was a correlation between the usage or using electronic devices for a long period of time and MPOD level. Higher usage of electronic devices lead to the lower of MPOD level.

Keywords: MPOD level/Blue light/M-POD Device/AMD

INTRODUCTION

Today, personal communication devices such as smartphone and computer laptop play an important role in our life. From waking up in the morning until going to the bed at night, we spend more and more time on these devices to work, to play, and to socialize with people surrounding our life. In 2014, Thailand Electronic Transaction Development Agency (Public Organization) or ETDA, under the Ministry of Information and Communication Technology, conducted a survey with Internet users and found that, on the average, Thai users spent their time on the Internet about 50.4 hours per week, or 7.2 hours per day. This means that looking at electronic device screens takes up about 1/3 of our one day time (Electronic Transaction Development Agency, 2014).

As a result of our behavior change in these few years, our eyes had been working hard. And we were concerned that continuous exposure to the light from these devices can damage our eyes. We were concerned that this can lead to Computer Vision Syndrome (CVS). CVS is the eye related symptom, probable causing 64-90% from using the smartphones and computer devices. The symptom includes eye soring, eye strain, tired eyes, irritation, redness, blurred vision and diplopia as well as headache, neck pain, and back pain. This symptom gets more severe with increasing the time on these computer devices (Rosenfield M, 2011). And in addition to CVS, we are more concerned now with the lighting from these devices. The light can damage retina, leading to Age-related Macular Degeneration (AMD) which is the cause of blindness. There are many factors that increase risk of AMD such as aging, family history, smoking, light iris coloration, dietary habit, and phototoxic exposure. When light comes to the eyes, it will pass through cornea and lens. Although cornea filters some ultraviolet or UV light, most light will reach the retina (Vimol Srisukh, 2014).

From all wavelengths visible to our eyes, blue light is high energy visible (HEV) wavelengths, high frequency light that can release free radical in the retina. Blue light exists in the

sunlight and in the electronic devices such as LED light, fluorescent tube, TV, computer screens, laptop, tablets and smartphones.

The researcher in this paper was interested in finding out how electronic device effects Macular Pigment Optical Density (MPOD) by using measurement instrument: Macular Pigment Optical Densitometer (M-POD) to measure and compare MPOD levels of infrequent/low usage people and frequent/high usage people that used the electronic devices. It was believed that high Macular pigment can prevent AMD and low Macular pigment increases the risk of developing AMD (Hammond & Caruso-Avery, 2000). The researcher hoped that this study can provide further approach for planning and promoting for good health, preventing health problems caused by using these electronic devices, as well as providing primary data source for further studies by others.

Objective

To compare macular pigment optical density level (MPOD) between infrequent/low-usage persons ($\leq$ 5 hours/day) and frequent/high-usage persons of the electronic devices ($\geq$ 9 hours/day).

Scope of Research

Exploratory research to measure MPOD levels in subjects with various exposure to electronic devices.

Independent Variable: Duration of using electronic devices.

Dependent Variable: Macular pigment optical density (MPOD) Level.

LITERATURE REVIEW

Light is electromagnetic particles that move through space in waves. Such waves send out energy that varies by the wavelength where the shorter wavelength has higher energy. The wavelengths that are corresponded for our eyes is the visible light. We see this visible light in colors: indigo, blue, violet, green, yellow, red and orange. In comparison with the visible light, blue light has much shorter wavelength and therefore carry more energy. Blue light, with a wavelength between 380nm and 500nm, is one of the shortest and highest-energy wavelengths.

The sources of blue light are the sun, digital displays (computers, Television, mobile phones, tablets and laptops), LED and fluorescent lighting. Studies indicate that when human eyes have been exposed to the blue light spectrum over the long period of time, they could have severely irreversible eye damage (Ronald Melton, 2014).

Macular Pigment Optical Density or MPOD is pigment that plants synthesize for coloration and absorption of light energy. Carotenoids have two kinds: Xanthophylls and Carotenes. Carotenoids protect the retina and particularly the macula by (1) Acting as a filter (2) Reducing oxidative stress. The MPOD diminishes the amount of blue light hitting the photoreceptor cells by absorbing light in spectrum of 400-450 nm, (peak approximately 460 nm), so it acts as a blue-light filter. The MPOD also protects the macula from oxidative stress by serving as antioxidants which neutralize such reactive oxygen species in the inner retina and photoreceptor RPE complex (Osborne, Núñez-Álvarez & del Olmo-Aguado, 2014). The MPOD's capacity to filter blue light and reduce oxidative stress has led the researchers to believe that MPOD could help protect the persons from developing eye diseases like Age-related Macular Degeneration (AMD) (Bernstein, Delori, Richer, van Kuijk & Wenzel, 2010).

The Macular Pigment Optical Densitometer (M-POD)/M-POD Device is to measure the MPOD levels using the principle of heterochromatic flicker photometer (HFP) by displaying two light stimuli of different wavelengths that the patient perceives as a flicker. The light stimuli alternates between a blue light and a green light. Blue light is a short wavelength and absorbed by the macular pigment, green light is longer wavelength which the macular do not absorb (Osborne et al., 2014). The MPOD level is estimated as at the log ratio of radiance of blue light needed at the fovea compared with the parafovea (Howells, Eperjesi & Bartlett, 1990).

Age-related macular degeneration (AMD) is a deterioration of the eye's macula, the small area in the retina that is responsible for our vision, allowing us to see clear details. AMD is the leading cause of vision loss and blindness among people who are 65 years old and older. There are signs and symptoms of macular degeneration, e.g. blurry distance and/or reading vision, hazy vision, distorted vision, dark gray spots or blank spots in your vision and loss of central vision.

The previous study by Taylor et al. (1990) on " Visible light and risk of age-related macular degeneration" and found that sunlight (blue light and visible light) exposure had been

suggested as a cause of AMD. To examine this, they collected historic data of ocular sun exposure in 838 watermen who work on the Chesapeake Bay. The presence and severity of AMD was assessed in stereo macular photographs. Another related research paper from Boulton M et al. (1995) on "Blue Light-Induced Reactivity of Retinal Age Pigment: In Vitro Generation of Oxygen-Reactive Species" found that exposure of the eye to intense light, particularly blue light, can cause irreversible, oxygen-dependent damage to the retina. They also found that lipofuscin-photosensitized aerobic reactions lead to enhanced lipid peroxidation as measured by accumulation of lipid hydroperoxides and malondialdehyde in illuminated pigment granules. Hydrogen peroxide is only a minor product of aerobic photoexcitation of lipofuscin. They postulate that lipofuscin is a potential photosensitizer that may increase the risk of retinal photodamage and contribute to the development of age-related maculopathy.

METHODOLOGY

Research Design

This independent study was a survey research that required capturing personal data and measurement of MPOD levels by using Macular Pigment Optical Densitometer or M-POD device. Samples were randomly recruited from working Thai people in the office building, and factory with good health, age between 25-55 years old, willing to respond to questions on the personal data record form, and being eye-tested using M-POD device. In this study, there were 162 subjects. The subjects were divided equally into three groups of 54: the low usage with time spent on electronic device 5 hours or less per day ($\leq$5 hours/day), the moderate usage with time spent more than 5 hours but less than 9 hours per day (5.1-8.9 hours/day), and the high usage with time spent 9 hours or more per day ($\geq$9 hours/day), following inclusion and exclusion criteria.

Research Tools

Tools used for the research were Personal Data Record Form and M-POD device.

Personal Data Record Form

The form captures subject's personal data, time spent per day using the electronic device, and MPOD test result. The personal data includes name, date of birth, age, city of residence, nationality, gender, occupation, whether or not wear glasses or contact lens, history of

cataract extraction, family history of AMD, body weight and height, smoking habits, alcohol beverage consumption, iris color, vitamins and supplement intake, and current illness.

The Macular Densitometer is a device developed and originally described by Wooten, Hammond, Land and Snodderly (1999) to measure MPOD level.

The device uses the principle of heterochromatic flicker photometer (HFP) to obtain a valid measure of MPOD level by displaying two light stimuli of different wavelengths that the patient perceives as a flicker. The light stimuli alternates between a blue light of short wavelength (460 nm), which is maximally absorbed by the macular pigments, and a green light of longer wavelength (570 nm), which the pigments do not absorb. The MPOD level is estimated as at the log ratio of the radiance of blue light needed at the fovea compared to the parafovea (Howells et al., 1990). Each MPOD test takes approximately 2-3 minutes from start to finish. The examination is contact-free and free of pain. A dilation of pupils is not required.

Research Procedure

1. The researcher made announcement for the subject to apply.
2. Randomly recruited subject from various event or office building or factory
3. Asked the subject to fill out the personal data record form and measure MPOD level
4. Randomly selected subject that was in the inclusion criteria and repeated until getting total number of required sample size.
5. Recorded the data.

Statistics used for the data Analysis

The researched used Descriptive Analysis such as quantity, percentage, average, means and standard deviation and compared MPOD levels from three groups: the low usage: 5 hours or less per day, the moderate usage: 5.1-8.9 hours per day and the high usage: 9 hours or more per day, using ANOVA, with confidence interval 95% (p-value = 0.05)

RESULT

Table 1 The Information about Number of Subjects and its Relative Percentage that were Categorized by Usage Group.

Information	Number of subjects (Percentage)			Total
	The low usage (≤ 5 hrs/d)	The moderate usage (5.1-8.9 hrs/d)	The high usage (≥ 9 hrs/d)	
Gender				
Male	24 (44.4)	24 (44.4)	22 (40.7)	70 (43.2)
Female	30 (55.6)	30 (55.6)	32 (59.3)	92 (56.8)
Total	**54 (100)**	**54 (100)**	**54 (100)**	**162 (100)**
Wearing eyeglasses				
Yes	14 (25.9)	22 (40.7)	20 (37.0)	56 (34.6)
No	40 (74.1)	32 (59.3)	34 (63.0)	106 (65.4)
Total	**54 (100)**	**54 (100)**	**54 (100)**	**162 (100)**
Occupation				
Office staff	11 (20.4)	29 (53.)	41 (75.9)	81 (50.0)
Housework	3 (5.6)	6 (11.1)	1 (1.9)	10 (6.2)
Student	2 (3.7)	2 (3.7)	0 (0.0)	4 (2.5)
Non-Routine officer	32 (59.3)	13 (24.1)	5 (9.3)	50 (30.9)
Other (teacher, doctor, etc.)	6 (11.1)	4 (7.4)	7 (13.0)	17 (10.5)
Total	**54 (100)**	**54 (100)**	**54 (100)**	**162 (100)**

Note. The number of subjects in each group was equal to 54 subjects.

Table 1 showed that the low and moderate usage group had 24 male subjects (44.4%) and 30 female subjects (55.6%), the high usage group had 22 male subjects (40.7%) and 32 female subjects (59.3%). The total number of female in all usage group was 92 (56.8%) while its male was 70 (43.2%).

Number of subjects that were non-wearing eyeglasses were 106 (65.4% of total). Number of subjects wearing eyeglasses were 56 (34.6%)

81 subjects (50%) were office staff.

Table 2 Mean and Standard Deviation (SD) of Usage Hours and MPOD Levels in each Electronic Device Type.

Electronic devices	No.	Usage (hrs/d)		MPOD Levels	
		Mean	SD	Mean	SD
Computer	4	4.75	3.76	0.63	0.20
Mobile Phone	13	5.31	3.12	0.49	0.14
TV	6	2.83	0.75	0.61	0.16
Computer + TV	2	9.50	2.12	0.51	0.11
Computer + Mobile Phone	24	8.67	3.81	0.42	0.13
Mobile Phone + TV	42	5.56	2.01	0.63	0.15
Computer+Mobile Phone+TV	71	8.97	2.86	0.51	0.17
Total	**162**	**7.42**	**3.37**	**0.53**	**0.17**

Table 2 showed usage of Computer, Mobile Phone, and TV. For single device usage, Mobile Phone was the most used device with the highest mean (standard deviation) of 5.31 (3.12) hours per day, then TV was the second most used device with mean (standard deviation) of 2.83 (0.75) hours per day, and computer was next with the lowest mean (standard deviation) of 4.75 (3.76) hours per day, respectively. In contrary, Mobile Phone had the lowest MPOD level with mean (standard deviation) of 0.49 (0.14), then TV had the second lowest MPOD level with mean (standard deviation) of 0.61 (0.16), then Computer had the highest MPOD level with mean (standard deviation) of 0.63 (0.20).

For combination usage of two devices, Mobile Phone + TV was the most used with the lowest mean of 5.56, then Computer + Mobile Phone was the second most used with mean of 8.67 (3.81), then Mobile + TV was next with mean of 5.56 (2.01). Note that Mobile Phone + TV had mean of MPOD level at 0.63 which was relatively the same as the mean of MPOD level of Computer.

The combination usage of three devices, Computer + Mobile Phone + TV was the most used of all, with 71 participants and mean (standard deviation) of 8.97 (2.86).

Table 3 Mean and Standard Deviation (SD) of Usage Hours and MPOD Levels in each Electronic Device Type and Groups of usage.

Electronic Devices	Usage Hours (hrs/d)									MPOD Levels								
	The low usage (≤ 5 hrs/d)			The moderate usage (5.1-8.9 hrs/d)			The high usage (≥ 9 hrs/d)			The low usage (≤ 5 hrs/d)			The moderate usage (5.1-8.9 hrs/d)			The high usage (≥ 9 hrs/d)		
	No.	Mean	SD	No.	Mean	SD	No.	Mean	SD	No.	Mean	SD	No.	Mean	SD	No.	Mean	SD
Computer	2	1.50	0.71	2	8.00	0.00	0	0	0	2	0.76	0.20	2	0.51	0.10	0	0	0
Mobile Phone	8	3.13	1.36	3	7.67	0.57	2	10.50	0.71	8	0.57	0.10	3	0.42	0.07	2	0.31	0.10
TV	6	2.83	0.75	0	0	0	0	0	0	6	0.61	0.16	0	0	0	0	0	0
Com.+TV	0	0	0	1	8.00	0.00	1	11.00	0.00	0	0	0	1	0.58	0.00	1	0.43	0.00
Com.+MPhone	5	3.60	1.14	9	7.22	0.97	10	12.50	1.71	5	0.54	0.08	9	0.45	0.08	10	0.32	0.10
MPhone+TV	22	4.02	0.82	17	6.76	0.90	3	10.00	1.00	22	0.73	0.11	17	0.54	0.10	3	0.38	0.05
Com.+MPhone+TV	11	4.82	0.41	22	7.14	0.77	38	11.24	1.63	11	0.76	0.11	22	0.56	0.11	38	0.40	0.10
Total	**54**	**5.00**	**1.91**	**54**	**7.11**	**0.86**	**54**	**11.37**	**1.67**	**54**	**0.68**	**0.14**	**54**	**0.53**	**0.11**	**54**	**0.38**	**0.10**

Table 3 showed the comparison of different usage levels (Low, Moderate and High) among Computer, Mobile Phone, and TV. For the Low usage level, the researcher found that, for single device usage, Mobile Phone was the most used device with mean (standard deviation) of 3.13 (1.36) hours per day. Mobile Phone users had the lowest MPOD level with mean (standard deviation) of 0.57 (0.10). For combination usage of two devices, Mobile Phone + TV was the most used with mean (standard deviation) of 4.02 (0.82) hours per day. For combination usage of three devices, Computer + Mobile Phone + TV had 11 subjects, with highest mean (standard deviation) of 4.82 (0.41) hours per day.

For the Moderate usage level of single device usage, Mobile Phone was the most used device with mean (standard deviation) of 7.67 (0.57) hours per day. Mobile Phone users had the lowest MPOD level with mean (standard deviation) of 0.42 (0.07). For combination usage of two devices, Mobile Phone + TV was the most used with mean (standard deviation) of 6.76 (0.90) hours per day, but Computer + Mobile Phone had the highest mean (standard deviation) of 7.22 (0.97) hours per day. For combination usage of three devices, Computer + Mobile Phone + TV was the most used in the Moderate usage group and had mean (standard deviation) of 7.14 (0.77) hours per day.

For the High usage level, Mobile Phone was the most used device with mean (standard deviation) of 10.50 (0.71) hours per day. Mobile Phone had the lowest MPOD level with mean (standard deviation) of 0.31 (0.10). For combination usage of two devices, Computer + Mobile Phone was the most used with the highest mean (standard deviation) of 12.50 (1.71) hours per day. For combination usage of three devices, Computer + Mobile Phone + TV was the most used in the High usage group and had mean (standard deviation) of 11.24 (1.63) hours per day.

Table 4 Mean and Standard Deviation of MPOD Levels in each Usage Category of the Electronic Device.

Usage Category	**Mean of MPOD level**	**SD**	**Mean Difference**	**F**	**P-value**
The low usage ($\leq$ 5 hrs/d)	0.68 (a)	0.14	a-b = 0.15*	91.71	< 0.00
The moderate usage (5.1-8.9	0.53 (b)	0.11	a-c = 0.30*		
hrs/d)	0.38 (c)	0.10	b-c = 0.15*		
The high usage ($\geq$ 9 hrs/d)					

Note. The number of subjects in each group of usage was equal to 54 subjects.

Table 4 showed the result of ANOVA method found that the difference in MPOD levels in each usage category were statistically significant at $P < 0.001$. The mean of MPOD levels of the Low usage was higher than that of the Moderate usage (Mean Difference = 0.15) and the High usage (Mean Difference = 0.30), respectively. The mean of MPOD levels of the Moderate usage was higher than that of the High usage (Mean Difference = 0.15).

DISCUSSION AND CONCLUSION

Discussion

An analysis of subject information

From the data, the number of subjects and its relative percentage that were categorized by usage group showed that the percentage of subjects in male and female for each group were nearly equal. The total number of female in all usage groups was 92 (56.8%) while its male was 70 (43.2%). In each group there were more non-wearing-eyeglasses subjects than wearing-eyeglasses subjects. In the moderate usage and the high usage, percentage of wearing-eyeglasses subjects was higher than that in the low usage.

The comparison of different usage levels (Low, Moderate and High) among Computer, Mobile Phone, and TV. For the Low usage level, the researcher found that, for single device usage, Mobile Phone was the most used device with mean (standard deviation) of 3.13 (1.36) hours per day. Mobile Phone users had the lowest MPOD level with mean (standard deviation) of 0.57 (0.10). For combination usage of two devices, Mobile Phone + TV was the most used with mean (standard deviation) of 4.02 (0.82) hours per day. For combination usage of three devices, Computer + Mobile Phone + TV had 11 subjects, with highest mean (standard deviation) of 4.82 (0.41) hours per day. For the Moderate usage level of single device usage, Mobile Phone was the most used device with mean (standard deviation) of 7.67 (0.57) hours per day. Mobile Phone users had the lowest MPOD level with mean (standard deviation) of 0.42 (0.07). For combination usage of two devices, Mobile Phone + TV was the most used with mean (standard deviation) of 6.76 (0.90) hours per day, but Computer + Mobile Phone had the highest mean (standard deviation) of 7.22 (0.97) hours per day. For combination usage of three devices, Computer + Mobile Phone + TV was the most used in the Moderate usage group and had mean (standard

deviation) of 7.14 (0.77) hours per day. For the High usage level, Mobile Phone was the most used device with mean (standard deviation) of 10.50 (0.71) hours per day. Mobile Phone had the lowest MPOD level with mean (standard deviation) of 0.31 (0.10). For combination usage of two devices, Computer + Mobile Phone was the most used with the highest mean (standard deviation) of 12.50 (1.71) hours per day. For combination usage of three devices, Computer + Mobile Phone + TV was the most used in the High usage group and had mean (standard deviation) of 11.24 (1.63) hours per day.

An analysis of the hypothesis test

The hypothesis was that the level of macular pigment optical density (MPOD) for infrequent/low-usage persons ($\leq$ 5 hours/day) is higher than that for frequent/high-usage persons ($\geq$ 9 hours/day).

The result found that the difference in MPOD levels in each usage category were statistically significant at $p < 0.05$. The mean of MPOD levels of the Low Usage was significantly higher than that of the Moderate Usage (0.68±0.14 and 0.53±0.11, $p < 0.05$ respectively). The mean of MPOD levels of the Moderate Usage was significantly higher than that of the High Usage (0.53±0.11 and 0.38±0.10; $p < 0.05$ respectively). And the mean of MPOD levels of the Low Usage was also significantly higher than that of the High Usage (0.68±0.14 and 0.38±0.10, $p < 0.05$ respectively). This result corresponded to the prior research by Margrain, Boulton, Marshall and Sliney (2004) which showed that light, in particular blue light, is a source of oxidative stress via its interaction with retinal chromophores. Therefore, a reduction in blue light exposure might reasonably be expected to reduce progression in AMD. Blue light causes damage to macular pigments, leading to the eye degenerative disease and eye disease (Kijlstra, Tian, Kelly & Berendschot, 2012; Osborne, Núñez-Álvarez & del Olmo-Aguado, 2014). In addition, this corresponded to the research by Boulton et al. (1995) that studied "Blue Light-Induced Reactivity of Retinal Age Pigment: In Vitro Generation of Oxygen-Reactive Species" and found that exposure of the eye to intense light, particularly blue light, can cause irreversible, oxygen-dependent damage to the retina. In addition, the chronic exposure to blue light or visible light may be related to the development of AMD (Taylor, West, Munoz, Rosenthal & Bressler, 1992).

Conclusion

The analysis above leads to the discussion about Long Term Blue Light Exposure Effect on Macular Pigment Optical Density (MPOD) according to the research objective. The result from comparing MPOD levels between the low-usage persons ($\leq$ 5 hours/day) and the high-usage persons of the electronic devices ($\geq$ 9 hours/day) showed that the low-usage persons had higher MPOD level than that of the high-usage persons of the electronic devices. There was a correlation between the usage or using electronic devices for a long period of time and MPOD level. Higher usage of electronic devices lead to the lower of MPOD level.

Application of this Study

For general public's interest, the result showed that Blue Light can affect MPOD Level, which is one of the factors for Age-related macular degeneration (AMD). The general public should be aware of the effect from using electronic devices "excessively", and the general public should be advised about how to prevent or avoid Blue Light in their daily life in order to maintain good healthy eyes.

For medical profession, the result showed that today people are exposed to Blue Light for long time. Medical professionals should promote the general public's awareness of how to prevent Blue Light in every day's life and should give advice on how to prevent possible damage being caused by long term exposure to Blue Light which is common in today's widespread use of electronic devices.

Suggestion for the Further Study

The study on whether or not changing lifestyle by reducing number of usage hours on electronic device would improve MPOD level.

REFERENCE

Bernstein, P. S., Delori, F. C., Richer, S., van Kuijk, F. J. & Wenzel, A. J. (2010).

The value of measurement of macular carotenoid pigment optical densities

anddistributions in age-related macular degeneration and other retinal disorders.

Retrieved November 10, 2015, from http://www.sciencedirect.com/science/article/pii/S0042698909004787

Bhosale, P., Larson, A. J., Frederick, J. M., Southwick, K., . . . Bernstein, P. S. (2004). *Identification and characterization of a Pi isoform of glutathione Stransferase(GSTP1) as a zeaxanthin-binding protein in the macula of the human eye.* Retrieved November 10, 2015, from http://www.ncbi.nlm.nih.gov/pubmed/15355982

Bone, R. A., Landrum, J. T., Fernandez, L. & Tarsis, S. L. (1988). *Analysis of the macular pigment by HPLC: Retinal distribution and age study.* Retrieved November 5, 2015, from http://www.researchgate.net/publication/19784495_Analysis_of_the_Macular_Pigment_by_HPLC_Retinal_Distribution_and_Age_Study

Boulton, M., Jarvis-Evans, J., Rozanowska, M., Korytows, W., . . . Sarna, T. (1995). *Blue light-induced reactivity of retinal pigment. In vitro generation of oxygen-reactive species*. Retrieved November 10, 2015, from http://www.researchgate.net/publication/15555690_Blue_light-induced_reactivity_of_retinal_pigment._In_vitro_generation_of_oxygen-reactive_species.

De La Paz, M. & Anderson, R. E. (1992). *Region and age-dependent variation in susceptibility of the human retina to lipid peroxidation*. Retrieved November 5, 2015, from http://iovs.arvojournals.org/article.aspx?articleid=2178631

Electronic Transaction Development Agency. (2014). *Thailand Internet User Profile 2014.* Retrieved November 1, 2015, from http://www.slideshare.net/Yakuzaazero/2557-37727346

Hammond, B. R. & Caruso-Avery, M. (2000). Macular pigment optical density in a southwestern sample. *Invest Ophthalmol Vis Sci, 41*,1492–1497.

Howells, O., Eperjesi, F. & Bartlett, H. (1990). *Measuring macular pigment optical density in vivo: a review of techniques.* Retrieved November 10, 2015, from http://www.ncbi.nlm.nih.gov/pubmed/21221629

Kijlstra, A., Tian, Y., Kelly, E. R., & Berendschot, T. T. (2012). Lutein: more than just a filter for blue light. *Progress in retinal and eye research*, *31*(4), 303-315.

Marilyn Haddrill. (2015, September 22). *Understanding Age-Related Macular Degeneration(AMD).* Retrieved November 5, 2015, from All about vision. http://www.allaboutvision.com/conditions/amd.htm

Osborne, N. N., Núñez-Álvarez, C. & del Olmo-Aguado, S. (2014). *The effect of visual blue light on mitochondrial function associated with retinal ganglions cells*. Retrieved November 10, 2015, from https://www.ncbi.nlm.nih.gov/pubmed/25193034

Ronald Melton, O. D. (2014, February). *Ultraviolet and Blue Light.* Retrieved November 10, 2015, from Review of optometry. http://www.reviewofoptometry.com/continuing_education/tabviewtest/lessonid/1

Rosenfield, M. (2011). *Computer vision syndrome: a review of ocular causes and potential treatments.* New York: The College of Optometrists.

Taylor, H. R., West, S., Munoz, B., Rosenthal, F. S. & Bressler, S. B. (1992). The long-term effects of visible-light on the eye. *Arch. Ophthalmol, 110*, 99–104.

Trieschmann, M., van Kuijk, F. J., Alexander, R., Hermans, P., . . . Bird, A. C. (2008). *Macular pigment in the human retina: Histological evaluation of localization and distribution.* Retrieved Novemver 3, 2015, from https://www.nature.com/articles/6702780

Vimol, S. (2014, April 6). *AMD what to eat to delay it?.* Retrieved November 1, 2015, from http://www.pharmacy.mahidol.ac.th/eng/knowledgeinfo.php?id=190

Wooten BR1, Hammond BR Jr, Land RI, Snodderly DM. (1999). *A practical method for measuring macular pigment optical density.* Retrieved December 5, 2015, from https://www.ncbi.nlm.nih.gov/pubmed/10509640