Songklanakarin J. Sci. Technol.
43 (2), 326-330, Mar. - Apr. 2021

http://www.sjst.psu.ac.th

Original Article

Effect of lighting on amplitude of accommodation among adolescence smartphone users

Sasitorn Taptagaporn[1], Santhanee Khruakhorn[2], Navapol Kanchanaranya[3], Suntaree Thitiwichienlert[3], and Wasana Lavin[4*]

[1] *Faculty of Public Health, Thammasat University, Rangsit Campus, Khlong Luang, Pathum Thani, 12120 Thailand*

[2] *Department of Physical Therapy, Faculty of Allied Health Sciences, Thammasat University, Rangsit Campus, Khlong Luang, Pathum Thani, 12120 Thailand*

[3] *Faculty of Medicine, Thammasat University, Rangsit Campus, Khlong Luang, Pathum Thani, 12120 Thailand*

[4] *Medical Engineering Graduate Program, Human Factors in Engineering and Ergonomics, Thammasat University, Rangsit Campus, Khlong Luang, Pathum Thani, 12120 Thailand*

Received: 8 June 2019; Revised: 10 January 2020; Accepted: 15 January 2020

Abstract

Inappropriate lighting level causes digital eye strain among smartphone users. This experimental study employed 33 students aged 12-15 years in 3 lower secondary schools in Pathumthani province, Thailand. Amplitude of accommodation (AA) was measured by using the minus lenses method and compared between pre and post experiment under 3 lighting levels (50, 300 and 600 lux). Data were collected from 15 June to 30 August 2016, and analyzed by repeated measures ANOVA. We found the amplitude of accommodation and speed of visual task were significantly different between pre-test and post-test among 3 lighting levels (p<.01). The change of AA was increased most in 50 lux, followed by 600 lux and 300 lux, respectively. The environmental lighting condition and prolonged smartphone use in children might cause adverse visual and health effects. Parents and teachers should advise their children on proper and limited use for health and safety.

Keywords: digital eye strain, amplitude of accommodation, smartphone use, lighting levels, adolescence

1. Introduction

The amplitude of accommodation (AA) is the maximum of accommodation exerted to move the focus from far to near point and the greatest increase in ability of the eye to change the refractive power of the lens to automatically focus on objects at various distances (Chiranjib & Ying, 2015; Ikaunieks, Panke, Seglioa, Dvede, & Krumioa, 2017). The functions of AA declines with age especially in over 40 year olds. (Heron, & Schor, 2001; Ikaunieks, Panke, Seglioa, Dvede & Krumioa, 2017). Many studies have shown that visual display terminals (VDTs) could induce temporary effects in the visual accommodation system such as transient myopia (Ciuffreda & Vasudevan, 2008; Sivaraman *et al.* (2015). However, several studies have suggested other causes such as vertical viewing angles of 20 degree effect (Chiranjib & Ying, 2015) and lighting that induced visual problems (Chiranjib & Nur, 2017). At present, visual problem is not only limited to computer use but can occur also in smartphone and other digital device use. The smartphone use for

*Corresponding author
Email address: wasana_lavin@hotmail.com

entertainment, playing games and social media such as Facebook and Instagram can cause eye and visual problems. Lighting condition had an influence on visual strain and well-being. Improper lighting could induce digital eye strain (DES) such as headaches, back and neck aches, drooping of eyelids, blurred vision, and decreased blink (Lavin, Taptagaporn, & Kruakorn, 2015; Mashkoori, Asadi, Yari, Allahdadi, Gharlipour, & Koohpaei, 2016). It could also change the visual acuity (VA) (Lin, Feng, Chao, & Tseng, 2008; Wolska, 1999) and the amplitude of accommodation (Wolska, 1999). According to the Occupational Safety and Health Administration (OSHA) and many research reported it is recommended that the lighting for VDT workstations should be between 300 to 700 lux (Bangor, 2000; Health and Safety Guildline, 2004; Ministry of Health, Brunei Darussalam, 2010; Parihar *et al.*, 2016) but for smartphone tasks, there is no recommendation. The aim of this study was to investigate the effects of lighting levels on the change of AA among adolescent. The purpose was to determine the satisfaction and prevention of AA change and DES in the lighting each levels.

2. Materials and Methods

2.1 Procedures

All 37 participants were introduced to the experiment until they had a clear understanding prior to the experimental session. Four participants were excluded because they could not complete the procedure. The experiment was carried out under the 3 levels of lighting, high condition (600 lx), moderate condition (300 lx), and dim condition (50 lx). The fluorescent lamps had a color temperature about 6500 Kelvin (K). The visual stimuli were displayed on a 5.1-inch diagonal screen smartphone. The auto brightness function was operated. Their visual acuity (VA) was measured at 6 meters by Snellen chart and recorded. All 3 lighting levels were set up in a random order. The game was used as the visual workload set for 15 minutes per section. During the 20-minute resting time, all participants were not allowed to do any digital work. During the experiment, viewing distance of smartphone display was fixed at 40 cm by using a headrest and chinrest to fix the head position. The angle of eye level was 15 degree (Prattana & Ladavichitkul, 2016; Saied, Kamel, & Mahfouz, 2013). The table height was 710 mm (Health and Safety Guildline, 2004; Monash University Procedure, 2017). The game was free downloaded from a Pet connects animals in Android by Google Play. Both eyestrain score and satisfaction were assessed using a 5-point Likert scale. The amplitude of accommodation was recorded before and after finishing each lighting level. The eyestrain score and satisfaction of lighting level were recorded, respectively.

2.2 Minus lens methods

All subjects were fixed at 40 cm viewing distance on chin rest during experiment. Before testing all participants were measured the amplitude of accommodation and after visual workload finished, all participants were immediately measured the amplitude of accommodation by the minus lenses method. The minus lenses were added, -0.25 diopter at a time until the subjects reported the first blur of the letter. The eyestrain score and satisfaction of lighting level were recorded, respectively. The researcher was trained on the minus lens method by the ophthalmologist and tried out with a similar group of 30 students who were not included in the target groups. The reliability was 0.8.

2.3 Data collection

This experimental study was to determine the amplitude of accommodation under different lighting levels among 33 students (11 males and 22 females) in lower secondary schools. They were 13 to 15 years old with mean age of 14.09 (± SD 0.67) years. Data were collected from 20 March to 31 July 2016 in 3 secondary schools in Pathumthani province, Thailand. The inclusion criteria were visual acuity not less than 1.0 or corrected-to-normal vision, use of smartphone at least 2 hours per day in 1 year. Participants had normal height and weight. They had no more than 3 symptoms of digital eye strain (DES) which consisted of; eye strain, irritate eye, photophobia, dry eyes, watery eye, blurred vision, red eye, headache, neck and shoulder pain (Lavin, Taptagaporn, Khruakhorn, & Kanchanaranya, 2018). The smartphone was selected from the most popular brand and model a previous study (Lavin *et al.*, 2018). The exclusion criteria were those with strabismus, ocular or systemic diseases affecting binocular vision and those who were using any medication that would have an impact on accommodation or convergence.

2.4 Statistical analysis

The sample size was calculated using a formula proposed by G-power *(version 3.1.9.4, available at:https://g-power.apponic.com/).* Data were analyzed by using SPSS version 20 software. ANOVA test and the Wilcoxon signed-rank test were used to show the difference of amplitude of accommodation after visual task under 3 lighting levels among all participants. All variables, consisting of AA, eye strain symptom and light satisfaction, were estimated from previous studies. The significance level was less than 0.05.

2.5 Ethical issues

This study was approved by Thammasart University Human Research Ethics committee No 3, and all participants and parents signed the informed “consent” and “assent” forms (COA NO. 104/2559).

3. Results and Discussion

3.1 Results

The highest-level digital eye strain symptom was found at 50 lux in 22 out of 33 students (66.7%). At 300 lux, 17 students had DES (51.5%) and at 600 lux, 20 students complained of DES (60.6%).

Table 2 shows the amplitude of accommodation change (Δ AA) between pre and post experiment in 3 lighting levels. The AA was found most increased in 50 lux (Δ AA =0.7 D), followed by 600 lux (Δ AA=0.6D) and 300 lux (Δ AA=0.49D), respectively.

Table 1. Participant characteristics factor (N = 33)

Personnel factor	N (%)
Gender	
Male	11 (33.3)
Female	22 (67.3)
Age (year) Mean ± SD	14.09.± 0.67
Body weight (Kg) Mean ± SD	51.1 ± 9.4
Height (Cm) Mean ± SD	158.2± 6.3
Visual acuity	
< 1	9 (27.3)
≥1	24 (72.7)
Allergy	
No	33 (100)
Yes	0 (0)
Exercises	
No/Irregular	3 (9.1)
Regular	30 (90.9)

Table 2. The Amplitude of accommodation (AA) change in 3 lighting levels (N=33)

Amplitude of accommodation (Diopter; D)	Lighting level		
	50 lux	300 lux	600 lux
Mean pretest (D)	3.88	2.53	3.20
Mean post-test (D)	4.58	3.02	3.80
Δ AA	0.7	0.49	0.6

3.2 Amplitude of accommodation (AA) pre-post test

Amplitude of accommodation measured by the minus lenses method differed between pre and post tests in all 3 lighting levels (F= 28.73, $p< .01$). This variable was analyzed with the Wilcoxon Signed - Rank test in each lighting levels. The result was shown that the pre and post tests were not significantly different (p>0.05).

3.3 Eye strain symptom

The lowest lighting level (50 Lux) caused the worst pain symptom with 2.15 score (SD = 0.79), followed by the highest level (600 Lux) with 1.97 score (SD = 0.79). The lowest symptom was at 300 lux with 1.88 score (SD = 0.61). Lighting level was insignificantly associated with eye strain symptoms (p=0.363).

3.4 Satisfaction

In the three lighting level, most participants were in 300 lux (42.4%), followed by 600 lux (36.4%), and the lowest level at 50 lux was 21.2%.

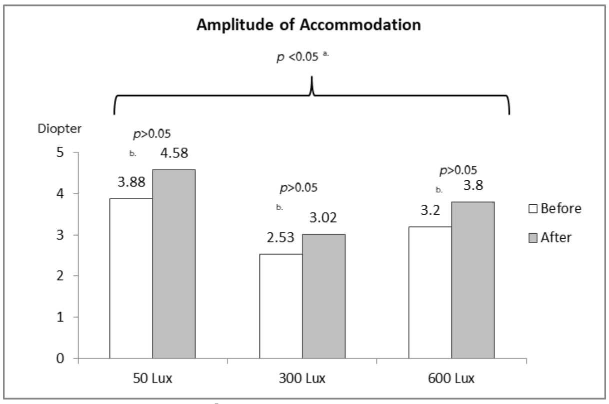
3.5 Discussion

Lighting had influences on smartphone users such as visual strain and well-being. Inadequate lighting level can cause digital eye strain consisting of; headaches, back and neck aches, drooping of eyelids, blurred vision, decreased blink (Mashkoori *et al.*, 2016; Lavin *et al.*, 2015) and changes in visual acuity (VA) (Lin *et al.*, 2008; Wolska, 1999) and the amplitude of accommodation (Wolska, 1999).

Table 3. The independent variable in 3 lighting levels (N=33)

Independent Variable	Lighting level			F	p-value
	50 lux	300 lux	600 lux		
Amplitude of accommodation before/after (Mean Rank)	3.88/ 4.58	2.53/ 3.02	3.20/ 3.80	28.73	<.01*
Eye strain	2.15	1.88	1.97	-	0.36

*Bonferroni Post-hoc Tests
Friedman Test
p-value < .05



a. Friedman Test
b. Wilcoxon Signed Ranks Test

Figure1. Amplitude of accommodation (AA) pre-post test in 3 lighting level, *p*-value < .05

The amplitude of accommodation changes between pre- post-test by minus lenses methods in 3 lighting levels were significantly reduced (p<.01). The Wilcoxon matched-pairs signed rank tests computing the difference between each lighting level were insignificantly association (p>.05). The present study was different from that of Wolska (1999), who found that surrounding luminance is associated significant reduction of the AA and visual fatigue in a 2 hour procedure (Wolska, 1999). In the present study we chose 15 minute that was a quite short period of visual task because the participants were adolescent. From the literature review, minimum duration of eye stimulation that may result in visual function changes was 15 minutes (Parihar, 2016). The researcher selected this group because we would like to be protected in the primary group. In the present study, there were two factors that affected the outcomes. Firstly is the individual factor. All subjects were asked to report the first perception of blurring. They were children who were easily affected with the interpretation of the result or fear about the wrong answer, sometime this would cause the AA to be overestimated (Benzoni & Rosenfield, 2012).

Lastly, the depth of field factor such as ocular aberration and pupil size (Urvoy, Barkowsky & Callet, 2013). This would require the depth of field factors such as ocular aberration and pupil size would also be the factors that affected the results (Urvoy, Barkowsky & Callet, 2013; Yekta *et al.*, 2013).

The most complaints of eye strain were at 50 lux (66.7 %), followed by 600 lux (60.6 %) and 300 lux (51.6 %), respectively. Three levels of eyestrain intensity were insignificantly different (p=.36). This study was consistent with the study of Richter *et al.* (2007) which studied in young and healthy groups. They found fewer report about the eye symptoms and discomfort after inducing the eye muscles with low load (Richter *et al.,* 2007).

The participants were most satisfied with the 300 lux (42.4%) followed by the highest lighting level 36.4%, and the lowest levels at 50 lux was 21.2%. This study agreed with Rempel (2012) and the NEC Display Solutions (2015), which recommended the level of light in classroom should be set between 150 – 500 lux but not specified for age groups of user and the kind of digital device. In our study, the game used in the experiment was negative polarity, it was more suitable in dark than bright environment (Bhagat, 2015). At lower lighting level (50 lux), the eye might have higher accommodation than of higher level (600 Lux) thus the amplitude of accommodation was higher. This study was similar with the study of Chiranjib (2017)ม which showed difference of amplitude of accommodation at 23 Lux to room illumination at 4 Lux (10.22 Diopter and 10.64 Diopter, respectively). However, it was studied in low levels. Unfortunately, there is no previous study to support our results to prove a significant interaction between three lighting levels and amplitude of accommodation.

4. Conclusions

The present study shows the most visual comfort and the most satisfaction of lighting level was at 300 lux. It is recommended to avoid playing game or using smartphone in lower light level (50 lux) because we found the eyestrain in the most participants, 22 from 33 (66.67%) and the amplitude of accommodation was the highest change in 50 lux (Δ AA =0.7 D). Although, in the present study, the sample size and the statistical power is too low to justify this recommendation**,** we recommend the level between 300 to 600 lux for adolescent in order to prevent digital eye strain. All parents and teachers should know and be aware of how to take care of their children.

Acknowledgements

The authors gratefully acknowledge all students who participated in this study and their assistance in the investigation.

References

Bangor, A.W. (2000). *display technology and ambient illuminat ion inf luences on visual fatigue at vdt workstations* (Doctoral thesis, Virginia Polytechnic Institute and State University, VA). Retrieved from https://pdfs.semanticscholar.org/9a83/79d4725b085bc550ee10b040ea979ac6a52b.pdf

Benzoni, J. A., Rosenfield, M., (2012). Clinical amplitude of accommodation in children between 5 and 10 years of age. *Journal of Optometric Vision Development, 43*(3),109-114.

Bhagat, Y. B. (2015). A Literature review on ergonomically study of VDT workstation operators. Paper presented at the IETE 46th Midterm symposium (pp. 6-8). New Delhi, India: *Special Issue of International Journal of Engineering, Economics and Management*.

Bowers, A. R., Meek, C., Stewart, N. (2001). Illumination and reading performance in age-related macular degeneration. *Clinical and Experimental Optometry, 84*(3), 139-147. doi:10.1111/j.1444-0938.2001.tb04957.x

Chiranjib, M., & Ying, L. S. (2015). Comparison of amplitude of accommodation in different vertical viewing angles. *Optometry and Visual Performance, 3*(5), 276-280.

Chiranjib, M., & Nur, Z. Z. (2017). Comparison of amplitude of accommodation in different room illumination while using VDU as a target. *International Journal of Ophthalmic Research, 3*(3), 243-248. doi:10.17554/j.issn.2409-5680.2017.03.64

Ciuffreda, K. J., & Vasudevan, B. (2008). Nearwork-induced transient myopia (NITM) and permanent myopia- is there a link? *Ophthalmic and Physiological Optics, 28*(2), 103–114. doi:10.1111/j.1475-1313.2008.00550.x

Health and Safety Guildline. (2017). Computer ergonomic: Workstation layout and lighting. Retrieved from http://www.publications.servicontario.ca.

Heron, G., & Schor, C. M. (2001). Age changes in the interactions between the accommodation and vergence systems. *Optometry and Vision Science, 78*(10), 754-762. doi:10.1097/00006324-200110000-00015

Ikaunieks, G., Panke, K., Seglioa, M., Dvede, A., & Krumioa, G. (2017). Accommodative amplitude in school age children. *Proceeding of the Lativian Academy of Sciences, 71(2)*, 387–391. doi:10.1515/prolas-2017-0065

Lavin, W., Taptagaporn, S., & Khruakhorn, S. (2015). Computer vision syndrome,CVS: one case report in children. *Thammasat Medical Journal, 15*(1), 1-7.

Lavin, W., Taptagaporn, S., Khruakhorn, S., & Kanchanaranya, N. (2018). Prevalence and associated risk factors of digital eye strain among children in secondary schools in Pathumthani province, Thailand. *Journal of the Medical Association of Thailand, 101*(7), 957-963.

Lin, C. J., Feng, W. Y., Chao, C. J., & Tseng, F. Y. (2008). Effects of VDT workstation lighting conditions on operator visual workload. *Industrial Health, 46*, 105–111.

Mashkoori, A. R., Asadi, S., Yari, A. R., Allahdadi, Z., Gharlipour, Z., & Koohpaei, A. R. (2016). Association between local illumination and visual fatigue among the research and development staffs of industry. *International Archives of Health Sciences, 3*(4), 157-162.

Ministry of Health Brunei Darussalam. (2017). Working with a computer (Visual with a display unit). Retrieved from http://www.moh.gov.bn/SiteCollectionDocuments/Occupational%20Health%20Division/guidelines/form02-07-10.pdf

Monash University procedure. (2017). Ergonomic design procedures. Retrieved from https://www.monash.edu/__data/assets/pdf_file/0003/147072/Ergonomic-Design-Procedure-02Feb17.pdf

NEC Display Solutions. (2017). How Display brightness affects successful implementation of Digital Signage applications. Retrieved from https://www.nec-display-solutions.com

Prattana, N., & Ladavichitkul, P. (2016). A Preliminary study of the effect visual angle on upper body posture of computer users. Paper presented at the IMECS (pp. 1-4) Hong Kong: *Proceedings of the International Multi Conference of Engineers and Computer Scientists 2*, 1-4.

Parihar, J. K., Jain, V. K., Chaturvedi, P., Kaushik, J., Jain, G., Parihar, A. K. (2016) Computer and visual display terminals (VDT) vision syndrome (CVDTS). *Medical Journal Armed Forces India*, *72* (3), 270-276

Rempel, A. G. (2012). Perceptual considerations for displays under varying ambient illumination (Doctoral thesis, the University of British Columbia,Vancouver, Canada. Retrieved from http://web.uvic.ca/~agrempel/ubc_2012_spring_rempel_allan.pdf

Richter, H. O., Crenshaw, A. G., & Lyskov, E. (2007). Accommodation–vergence performance after low levels of oculomotor load. *Scandinavian Journal of Work, Environment and Health, 3*, 60-67.

Saied, G. M., Kamel, R. M., & Mahfouz, M. M. (2013). For prolonged computer users: laptop screen position and sitting style cause more cervical musculoskeletal dysfunction compared to desktop, ergonomic evaluation. *Journal of Anthropology*, *2*(1), 1-4. doi:10.4172/2332-0915.1000117

Sivaraman, V., Rizwana, J. H., Ramani, K., Price, H., Calver, R., Pardhan, S., . . . Allen, P.M. (2015). Near work-induced transient myopia in Indian subjects. *Clinical and Experimental Optometry, 98,* 541–546. doi:10.1111/cxo.12306

Urvoy, M., Barkowsky, M., & Callet, L. (2013). How visual fatigue and discomfort impact 3D-TV quality of experience: a comprehensive review of technological, psychophysical, and psychological factors. *Springer, 68* (11-12), 641-655.

Wolska, A. (1999). Luminance of the surround and visual fatigue of VDT operators. *International Journal of Occupational Safety and Ergonomics*, *5*(4), 553-580.

Yekta, A., Hashemi, H., Ostadimoghaddam, H., Jafarzadehpur, E., Salehabadi, S., Sardari, S., . . . Norouzirad, R. (2013). Amplitude of accommodation and add power in an adult population of Tehran, Iran. *Iranian Journal of Ophthalmology*, *25*(3), 182-189.