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Effect of Display Polarity on Amplitude of Accommodation and Visual Fatigue

Nurulain Muhamad[1*], Nurul Hanna Moktaeffendi[2], Nur Syuhadah Azni[3]
** Corresponding Author*

[1] Centre of Optometry, Faculty of Health Sciences, Universiti Teknologi MARA, Kampus Puncak Alam, Cawangan Selangor, Malaysia, [2] Alam Optometry Clinic, Setia Alam, Selangor, Malaysia, [3] Focus Point Jalan Berakas, Bandar Seri Begawan, Brunei

nurulain5510@uitm.edu.my, nrlhnnaa@gmail.com, nursyuhadahazni@gmail.com
Tel: +60325844594

Abstract
This study aimed to assess the changes in the amplitude of accommodation under different display polarities and ascertain the effect of display polarities on visual fatigue. Thirty subjects randomly underwent a reading task for 30 minutes with both positive and negative display polarities. The amplitude of accommodation was measured, and subjects were required to complete a subjective symptoms questionnaire; both before and after the reading task. The amplitude of accommodation and visual fatigue symptoms were significantly reduced after the reading task, with both display polarities.

Keywords: Display polarity; amplitude of accommodation; visual fatigue

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1.0 Introduction

Nowadays, most people spend significant time in front of monitors, phones, and digital devices because they can complete many tasks without moving away. In recent years, digital device usage has increased significantly across all age groups, where extensive daily use for social and professional purposes is now considered normal (Sheppard & Wolffsohn, 2018). Electronic devices such as smartphones, tablets, and e- readers have increased significantly over the last decade (Lee & Kim, 2016). E-readers refers to two leading display technologies: electronic ink (E-ink) and the liquid crystal display (LCD), which were created to avoid the visual fatigue effect observed when using traditional electronic screens. Their advantages, such as low power consumption and sunlight readability, have increased their popularity among the general public (Benedetto et al., 2013). Initially, e-readers did not have a backlight. However, readers requested that it be able to be used in low-light environments, and many e-readers now include an integrated light (Behler & Lush, 2011). Tablets and smartphones are also popular reading devices due to their portability, larger screens, and display of colored text and images. When reading plain text on these devices, the user can change the letter size and text-background contrast polarity, i.e., whether the text is presented as black letters on a white background or white letters on a black background.

2.0 Literature Review

2.1 Display polarity

One of the essential factors in vision performance, such as reading, is contrast (Bernal-Molina et al., 2019). The stimulus for vision may be impaired if there is insufficient contrast because contrast improves object visibility and legibility (Chen & Muhamad, 2019). Differences in luminance do not solely determine contrast. Polarity is one of the other factors that contribute to contrast. A darker target on a lighter background improved visual

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performance by increasing the target legibility and visibility (Buchner & Baumgartner, 2007; Piepenbrock et al., 2014). Nowadays, most electronic screens have light (positive polarity) and dark modes (negative polarity). Positive polarity is when the dark text is presented on the light background, while negative polarity presents light text on the dark background (Hirota et al., 2018). Positive polarity reduces the reflected light visibility. Therefore, it is more conducive to viewing for some instances with glare or reflection problems. When using electronic screens in a dark environment, the dark mode is more conducive to reducing visual fatigue (Erickson et al., 2020). However, this study did not agree on which display mode best reduces visual fatigue (Erickson et al., 2020). The visual load caused by prolonged accommodation in near vision is underestimated, despite being a significant cause of asthenopia (Watten, 1994).

2.2 Accommodation

The accommodation has been identified as a factor in computer-related symptoms, which are predicted to be reported following prolonged smartphone use (Narawi et al., 2020). Accommodation is the process by which the eye shifts focus from distant to near images by changing the lens shape caused by the ciliary muscle's impact on the zonular fibers (Kirkwood & Kirkwood, 2013) while the amplitude of accommodation (AA) is the maximum amount of accommodation used to move the focus from a distance to a near point. It is also defined as the eye's maximum ability to automatically change the lens's power to focus on various lengths (Majumder, 2015). It has been reported that using a computer for more than 4 hours might cause substantial eye fatigue (Logaraj et al., 2014). Previous studies have investigated ways to assess visual fatigue using vergence and accommodation parameters objectively, including fusional vergence range, near the point of convergence (NPC), and high- frequency component (HFC) in the micro fluctuation of accommodation (Kajita M et al., 2001; Kim et al., 2014; Rosenfield, 2011). However, vergence and accommodation have reproducibility issues (Maeda et al., 2011). On the contrary, vergence and accommodation measurements were reported not to be appropriate criteria for detecting visual fatigue (Hirota et al., 2018). Visual display terminals (VDTs) have been found to temporarily impact the visual accommodation system (Taptagaporn et al., 2021). A study found that after using smartphones, accommodative functions, including monocular accommodative amplitude and relative accommodation, decreased significantly with age, with the effect being most pronounced in the mid-40s (Kwon et al., 2016). Because visual fatigue can be caused by vergence- accommodation conflict, previous studies used vergence and accommodation parameters to assess visual fatigue objectively (Kang et al., 2021).

2.3 Visual fatigue

Digital eye fatigue, or computer vision syndrome, is an eye and vision condition in long-term computer, tablet, and cell phone users (Randolph, 2017). According to recent studies, video display terminal users have a significant prevalence of visual discomfort, and most complaints after prolonged use of a computer include eye strain, blurred vision, double vision, tearing, irritation, redness, burning, and foreign body sensation (Lee & Kim, 2016). It also reduces the number of eye blinks, resulting in partial blinking that leads to dry eyes. When eye muscles constrict during visually demanding jobs, such as constantly gazing at computer monitors, it will cause visual fatigue. The eyes can become irritated and uncomfortable because of the tightening of the eye muscles. The use of electronic devices continues to grow, especially among young university students, due to higher usage even during class hours (Haque et al., 2016). The visual fatigue prevalence among university students worldwide is 46% to 71% (Han et al., 2013). Negative polarity or dark mode is suitable for dim surroundings at night because it can reduce visual fatigue (Xie et al., 2021). The prevalence of visual fatigue increases with the widespread use of computers and smartphones (Hirota et al., 2018). Blurred vision, diplopia, and illusory movement or flicker of words at a close viewing distance are common signs of visual fatigue (Zheng et al., 2021).

2.4 Duration of reading activities and accommodation

Activities that require intense eye use can cause visual fatigue especially prolonged near viewing, such as reading (Grove & Kündig, 2016). Digital eye fatigue, ocular discomfort, and visual disruption appear after using a digital device for two or more hours and prolonged daily use. Digital device for two or more hours and prolonged daily use. Tiredness and dryness are the most frequent signs of digital eye fatigue (Meyer et al., 2021). Some studies investigate the changes in accommodation and vergence after reading with a smartphone. Still, they are not comprehensive because only selected parameters (accommodative amplitude and fusional convergence amplitude) have been evaluated (Phamonvaechavan & Nitiapinyasagul, 2017). However, some studies have found that the amplitude of accommodation decreases after using a smartphone for 30 minutes (Kwon et al., 2016; Park et al., 2014). This may result from the tonic accommodation brought on by extended close work. Continuously reading from a smartphone for 20 minutes' increases symptoms such as blurry vision while reading, blurry distance vision after the task, difficulties focusing from one distance to another, eyestrain, itchy or burning eyes, sensitivity to bright lights, dry eyes, and eye discomfort (Antona et al., 2018). Compared to reading a book, another study found that smartphone use for 30 minutes dramatically reduced monocular amplitude accommodation, while reading a book caused a significant increase in accommodation lag in young adults (Park et al., 2014).

Previous research in the literature has found no agreement on the effect of display polarity on accommodation and visual fatigue. Only a few studies have been conducted to assess accommodation status with different polarities. The study discovered no difference in eye accommodation with different polarity (Bernal-Molina et al., 2019). However, the scope of the study was limited to objective measurements, with no consideration for subjective evaluation. To bridge the gaps, therefore, this study aims to determine the accommodation status objectively and subjectively evaluate the visual fatigue following prolonged use of digital devices with different display polarity.

3.0 Methodology

3.1 Research design

This cross-sectional study was conducted for six months, from January 2022 until Jun 2022. A cross- sectional study was a method in which the entire population or representative subject is observed at one moment in time. This study was carried out at Fakulti Sains Kesihatan, UiTM Puncak

Alam. This study adhered to the Declaration of Helsinki and was approved by the university's Research Ethics Committee (FERC/FSK/MR/2022/0065).

3.2 Subject selection

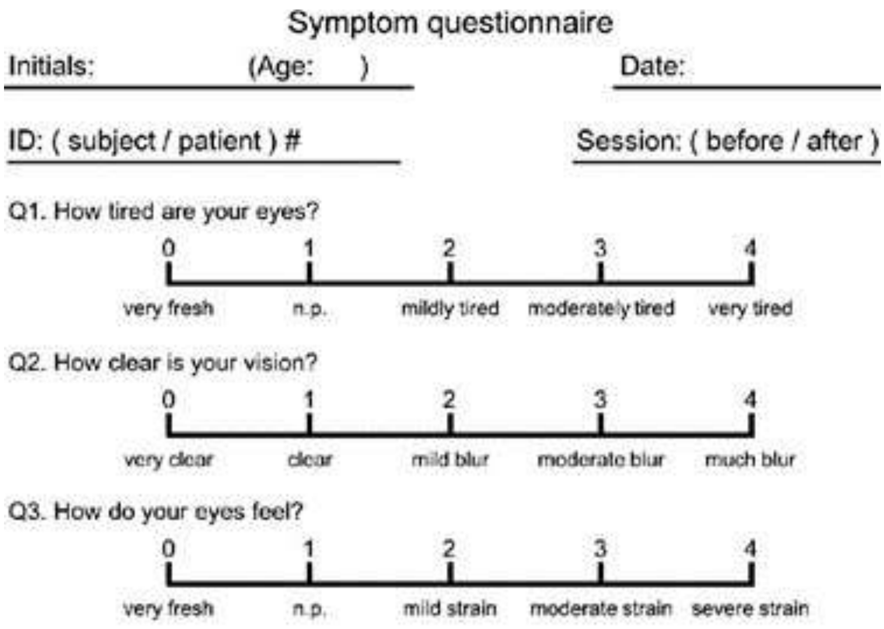
In this study, all subjects were recruited from the UiTM Puncak Alam student population aged 20 to 25 years. The inclusion and exclusion criteria for the subjects include best-corrected distance visual acuity of 6/6 or greater, near visual acuity of N5, reveals no ocular pathology, no prior ocular surgery, and normal clinical amplitudes of accommodation for their ages. The participants were screened if they had enough sleep and rested earlier before coming for the task. Sample size calculation as below:

$$= \left(\frac{1.96 \, * \, 1.4}{0.5}\right)^2 = 30$$

3.3 Research material

For the objective assessment, the amount of amplitude of accommodation was measured using Royal Air Force (RAF) rule and N6 as the target letter. For the subjective evaluation, a validated subjective symptoms questionnaire (Hirota et al., 2018) (Fig. 1) was adopted to assess the visual fatigue scale among the subjects before and after reading with different display polarity. The questionnaire consists of seven basic questions that are presented to the subjects before and after the digital near task. Question one to three was created to assess subjective eye symptoms, while questions four to seven were used to evaluate physical and mental discomfort. Each question was graded on a scale of zero to four; the subject needed to select one score for each. The visual fatigue resulting from the visual tasks was assessed through the total scores for questions one to three.

The digital device used in this study is a laptop, HP ProBook 440 (32.09 x 18.76 cm). The screen luminance for the positive and negative polarity was 221.1 cd/m2 and 187.5 cd/m2, respectively, while the screen brightness level was 100%. The ambient illumination was set at 200 lux. The visual fatigue and amplitude of accommodation assessments were measured under the two display polarity conditions. Both assessments were measured in random order. The text target was from the formal textbook (form 1) Malay language. The passage was developed with equal readability, in which the total words per paragraph were 60 words and 4 or 5 sentences in one paragraph (Fig. 2). There were 80 paragraphs chosen from the textbook that the subjects needed to read for 30 minutes. A laptop was placed on a 110cm high table. The high of the chair was 73cm. The horizontal distance between the table's edge and the screen was 30cm. The laptop was set at a 105- degree angle. The laptop's height can be adjusted to match the subject's height, resulting in a 15-degree viewing angle.



Symptom questionnaire

Initials: (Age:) Date:

ID: (subject / patient) # Session: (before / after)

Q1. How tired are your eyes?

0 very fresh — 1 n.p. — 2 mildly tired — 3 moderately tired — 4 very tired

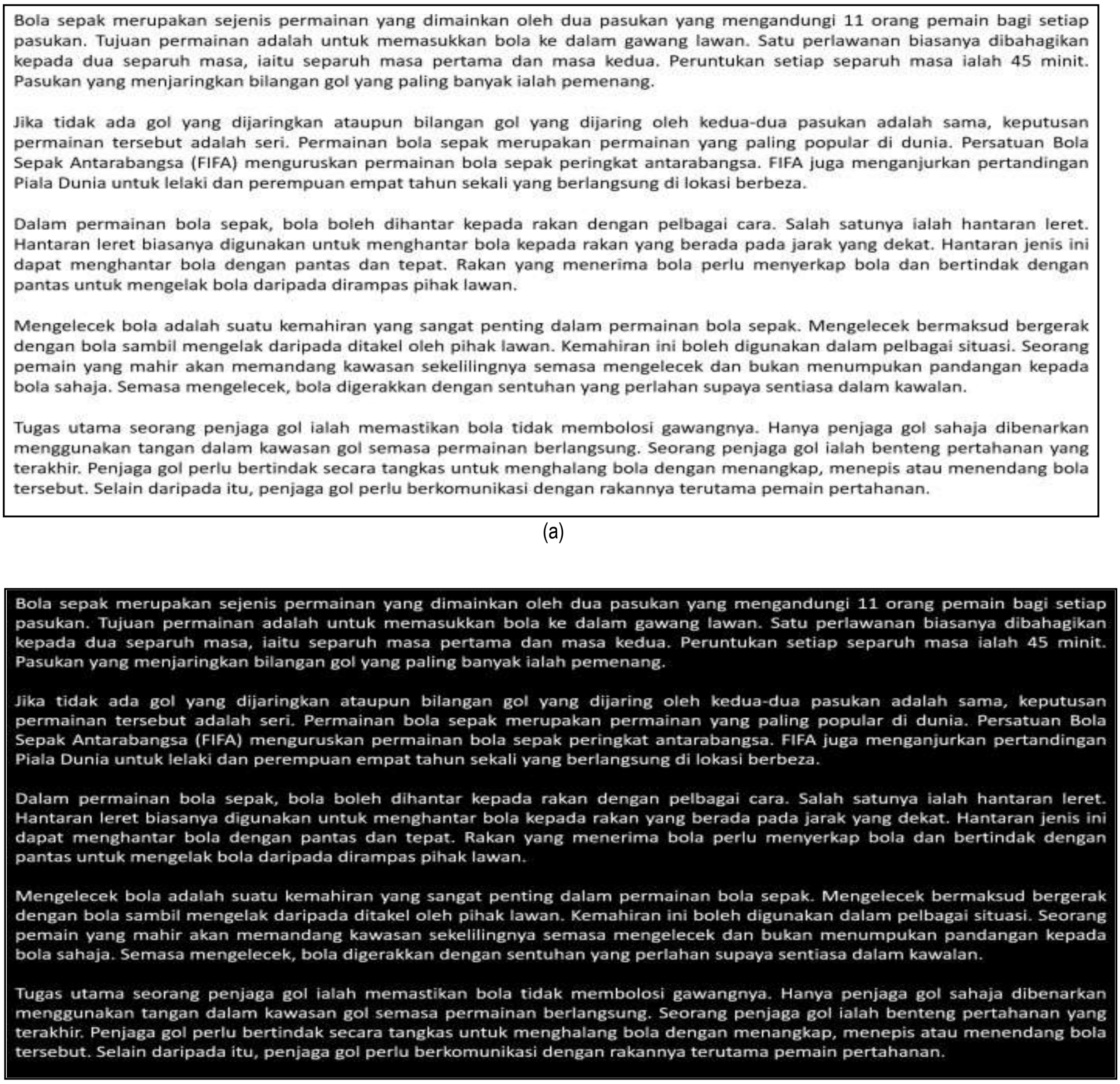
Q2. How clear is your vision?

0 very clear — 1 clear — 2 mild blur — 3 moderate blur — 4 much blur

Q3. How do your eyes feel?

0 very fresh — 1 n.p. — 2 mild strain — 3 moderate strain — 4 severe strain

Fig. 1: Visual fatigue scale questionnaire


Bola sepak merupakan sejenis permainan yang dimainkan oleh dua pasukan yang mengandungi 11 orang pemain bagi setiap pasukan. Tujuan permainan adalah untuk memasukkan bola ke dalam gawang lawan. Satu perlawanan biasanya dibahagikan kepada dua separuh masa, iaitu separuh masa pertama dan masa kedua. Peruntukan setiap separuh masa ialah 45 minit. Pasukan yang menjaringkan bilangan gol yang paling banyak ialah pemenang.

Jika tidak ada gol yang dijaringkan ataupun bilangan gol yang dijaring oleh kedua-dua pasukan adalah sama, keputusan permainan tersebut adalah seri. Permainan bola sepak merupakan permainan yang paling popular di dunia. Persatuan Bola Sepak Antarabangsa (FIFA) menguruskan permainan bola sepak peringkat antarabangsa. FIFA juga menganjurkan pertandingan Piala Dunia untuk lelaki dan perempuan empat tahun sekali yang berlangsung di lokasi berbeza.

Dalam permainan bola sepak, bola boleh dihantar kepada rakan dengan pelbagai cara. Salah satunya ialah hantaran leret. Hantaran leret biasanya digunakan untuk menghantar bola kepada rakan yang berada pada jarak yang dekat. Hantaran jenis ini dapat menghantar bola dengan pantas dan tepat. Rakan yang menerima bola perlu menyerkap bola dan bertindak dengan pantas untuk mengelak bola daripada dirampas pihak lawan.

Mengelecek bola adalah suatu kemahiran yang sangat penting dalam permainan bola sepak. Mengelecek bermaksud bergerak dengan bola sambil mengelak daripada ditakel oleh pihak lawan. Kemahiran ini boleh digunakan dalam pelbagai situasi. Seorang pemain yang mahir akan memandang kawasan sekelilingnya semasa mengelecek dan bukan menumpukan pandangan kepada bola sahaja. Semasa mengelecek, bola digerakkan dengan sentuhan yang perlahan supaya sentiasa dalam kawalan.

Tugas utama seorang penjaga gol ialah memastikan bola tidak membolosi gawangnya. Hanya penjaga gol sahaja dibenarkan menggunakan tangan dalam kawasan gol semasa permainan berlangsung. Seorang penjaga gol ialah benteng pertahanan yang terakhir. Penjaga gol perlu bertindak secara tangkas untuk menghalang bola dengan menangkap, menepis atau menendang bola tersebut. Selain daripada itu, penjaga gol perlu berkomunikasi dengan rakannya terutama pemain pertahanan.

(a)

Bola sepak merupakan sejenis permainan yang dimainkan oleh dua pasukan yang mengandungi 11 orang pemain bagi setiap pasukan. Tujuan permainan adalah untuk memasukkan bola ke dalam gawang lawan. Satu perlawanan biasanya dibahagikan kepada dua separuh masa, iaitu separuh masa pertama dan masa kedua. Peruntukan setiap separuh masa ialah 45 minit. Pasukan yang menjaringkan bilangan gol yang paling banyak ialah pemenang.

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(b)

Fig. 2: Illustration of two display polarities text. (a) Example of text in positive polarity; (b) text in negative polarity.

3.4 Procedure

Each subject underwent the task in the sequence shown in Fig. 3. The total experimental time was 90 to 100 minutes. The participants entered the experimental room and relaxed their eyes to get a good visual state for 5 minutes. They were asked to seat comfortably and hold head straight. Then, look in all four directions for two or three seconds each, up, down, left, and right without moving their head. After the relaxation, the experimental process was explained to the subjects to ensure they understood the task. Next, they were required to fill out the subjective visual fatigue questionnaire (pre-questionnaire), and the subject's amplitude of accommodation (pre-AA) was measured before the reading task. The participant then sat 50cm before the laptop and adjusted the sitting position. The reading process started once the participant was ready. The task was reading texts on two different display polarities randomly. After 30 minutes, the subjects were required to fill out the subjective visual fatigue questionnaire (post-questionnaire), and the subject's amplitude of accommodation was measured (post-AA). After completing the first task, the washing period was given, and the step was repeated with another display polarity for another 30 minutes.

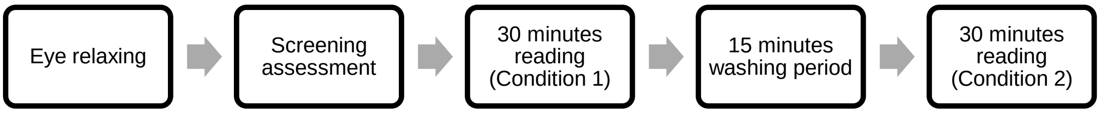

Fig. 3: Flowchart of the procedure

3.5 Statistical analysis

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) Statistics software version 20. The effect of display polarity on AA and visual fatigue after reading and comparison of AA between different types of polarity were analyzed with Wilcoxon signed rank test. To evaluate the relationship between objective and subjective determinations of visual fatigue, the correlation between the post-AA changes and the total subjective eye symptom score (Q1, Q2, and Q3), using single linear regression analysis, were evaluated.

4.0 Findings

There were 30 subjects with mean age of 23.53 ± 1.19 years. 76.7% (n=23) were females and 23.3% (n=7) were males. 60% (n=18) were spectacle wearers and 40% (n=12) were non-spectacle wearers. The average expected amplitude of accommodation based on subject population age was 10.72 ± 0.59 D.

4.1 The effect of display polarity on amplitude of accommodation after 30 minutes of reading

A Wilcoxon signed-rank test indicated significant AA changes after 30 minutes of reading with positive and negative display polarities (Table 1). Further analysis with Wilcoxon signed-rank test showed that the post-AA with positive and negative polarity was not significantly different. Nevertheless, the post-AA with negative polarity (9.97 ± 1.17 D) was slightly reduced compared to positive polarity (9.81 ± 1.39 D), yet it is not statistically significant (p = 0.398 (Table 2)).

Table 1. Mean of amplitude of accommodation (AA) before (pre-AA) and after (post-AA) 30 minutes of reading under two display polarities

Display polarity	Pre-AA Mean ± SD	Post-AA Mean ± SD	p-value
Positive	10.72 ± 0.58 D	9.97 ± 1.17 D	<0.001
Negative	10.72 ± 0.58 D	9.81 ± 1.39 D	<0.001

Table 2. Mean of post-AA between positive and negative display polarity

Variable	Mean ± SD		p-value*
	Positive polarity	Negative polarity	
Post-AA (D)	9.97 ± 1.17 D	9.81 ± 1.39 D	0.398

4.2 The effect of display polarity on visual fatigue after 30 minutes of reading

After 30 minutes of reading under two different display polarities, subjects responded moderately tired with positive polarity (n = 12, 40%) while mildly tired with negative polarity display (n = 11, 36.7%). In terms of clarity, both display polarities provide equal clarity. However, negative polarity was reported to cause moderate strain (n = 13, 43.3%) as compared to positive polarity display (n = 8, 26.7%) (Table 3). The subjective symptom questionnaire scores for Q1, Q2 and Q3 were significantly greater after the 30 minutes of reading task (p <0.001; Table 3).

Table 3. Distribution of visual fatigue symptoms reported before (pre) and after (post) 30 minutes of reading under two display polarities

Subjective visual fatigue symptom questionnaire	n (%)					
	Positive Polarity (PP)		p-value	Negative Polarity (NP)		p-value
	Pre	Post		Pre	Post	
Q1 (How tired are your eyes?)						
• Very fresh	1 (3.3%)	0 (0%)	<0.001	0 (0%)	0 (0%)	<0.001
• No problem	13 (43.3%)	6 (20%)		13 (43.3%)	6 (20%)	
• Mildly tired	7 (23.3%)	8 (26.7%)		9 (30%)	11 (36.7%)	
• Moderately tired	9 (30%)	12 (40%)		7 (23.3%)	7 (23.3%)	
• Very tired	0 (0%)	4 (13.3%)		1 (3.3%)	6 (20%)	
Q2 (How clear is your vision?)						
• Very clear	4 (13.3%)	2 (6.7%)	<0.001	3 (10%)	1 (3.3%)	<0.001
• Clear	20 (66.7%)	16 (53.3%)		20 (66.7%)	15 (50%)	
• Mild blur	5 (16.7%)	9 (30%)		6 (20%)	8 (26.7%)	
• Moderate blur	1 (3.3%)	2 (6.7%)		1 (3.3%)	5 (16.7%)	
• Much blur	0 (0%)	1 (3.3%)		0 (0%)	1 (3.3%)	
Q3 (How do your eyes feel?)						
• Very fresh	2 (6.7%)	0 (0%)	<0.001	0 (0%)	0 (0%)	<0.001
• No problem	18 (60%)	10 (33.3%)		19 (63.3%)	6 (20%0	
• Mild strain	8 (26.7%)	12 (40%)		8 (26.7%)	11 (36.7%)	
• Moderate strain	2 (6.7%)	8 (26.7%)		3 (10%)	13 (43.3%)	
• Severe strain	0 (0%)	0 (0%)		0 (0%)	0 (0%)	

4.3 Relationship between subjective and objective assessment

The change in post-AA after 30 minutes of reading with positive and negative display polarity was not significantly correlated with the total subjective eye symptoms score change. Mean total eye symptoms score were 1.87 ± 0.8 and 2.07 ± 0.8 for positive and negative polarity, respectively. A simple linear regression was calculated to predict post-AA based on the total eye symptoms score. A non-significant regression equation was found [F (1, 28) = 0.676, p=0.418], with an R^2 of 0.024 for positive polarity. The subject's predicted post-AA was equal to 9.50 ± 0.08D (eye symptoms score) when measured on a scale. The subject's post-AA was reduced by 0.08D for each scale of eye symptoms score. For negative polarity, the results were [F (1, 28) = 0.132, p=0.719], with an R^2 of 0.005. The subject's predicted post-AA was equal to 9.52 ± 0.04D (eye symptoms score) when measured on a scale. The subject's post-AA was reduced by 0.04D for each scale of eye symptoms score. Nevertheless, the reduction in post-AA was not significantly correlated with the subjective assessment.

5.0 Discussion

The present study evaluated the amplitude of accommodation and visual fatigue symptoms before and after 30 minutes of reading and compared positive and negative polarity.

5.1 Pattern of the amplitude of accommodation changes after 30 minutes of reading with different display polarity

The amplitude of accommodation (AA) was significantly reduced after 30 minutes of the reading task regardless of the display polarity being used. This is corroborated by a previous study that discovered a weakening of accommodation following 20 minutes of smartphone use while playing games with a white background (Narawi et al., 2020). This is based on the assumption that the human ciliary muscle is likely to become fatigued after prolonged contraction during near work due to excessive scattering of light (Wolffsohn et al., 2011). On the other hand, less blinking during computer work caused prolonged near point distance of accommodation (NPA), reduced AA, and increased period of accommodative tension after computer work as it possibly causes ongoing tension of the lens followed by excessive accommodation (Park et al., 2014). Contrary to the earlier study, the amplitude of accommodation before and after a near task for 30 minutes was insignificant (Wolffsohn et al., 2011). However, the effect was investigated with printed reading materials. In another study, the AA was found to be significantly decreased immediately after watching a smartphone, and the changes in AA were significantly superior to reading a book (Park et al., 2014). The reason behind this is the distance. According to a previous study, the mean working distance was closer for smartphones compared to reading books (Bababekova et al., 2011). Compared to longer working distances, the closer distance will place more demands on both ocular accommodation and convergence, especially if maintained for an extended time, potentially exacerbating symptoms (Rah et al., 2001). Besides, reading a book for sustained 30 minutes increases the ability to relax accommodation (Park et al., 2014). Previous studies had found that 30 minutes of reading was enough to cause changes in amplitude of accommodation (Kwon et al., 2016; Park et al., 2014).

It was found that the polarity effect was due to the display luminance effect (Taylor et al., 2009). The overall luminance of positive polarity displays was usually higher than that of negative polarity displays (Taylor et al., 2009) as from the formula of Michelson contrast $c=(Lt-Lb)/(Lt+Lb)$, it turned negative if text luminance, Lt, was lower than background luminance, Lb. A higher luminance display improved proofreading performance (Taylor et al., 2009). The quality of the retinal picture is anticipated to be improved because smaller pupils (owing to a higher luminance level) result in reduced higher-order aberrations (mostly spherical aberration) and greater depths of field. Even with real texts printed on physical paper, the light mode (dark ink letters on white paper) can cause visual fatigue as it makes the display emit high luminance (Blehm et al., 2005; Higuchi et al., 2003).

5.2 Effect of display polarity on visual fatigue after 30 minutes of reading

Subjective eye symptoms questionnaire scores of the subject were significantly greater after the visual task than initial scores with both polarities. This result supports previous evidence that also found increment of scores after 30 minutes of visual task by using 3D games, which strongly suggests that binocular stress may induce symptoms of eye and visual fatigue (Hirota et al., 2018). A study about types of eye strain explained that internal symptoms of strain, ache, and headache behind the eyes were linked to accommodative and binocular vision stress (Sheedy et al., 2003). Tired eyes, dry eyes, blurred vision, and headache were the most commonly reported symptoms after being exposed to a smartphone for 20 minutes (Narawi et al., 2020). This result is supported by the previous study, which found that increased symptoms include blurry vision, difficulty refocusing, eyestrain, sensitivity to light, and eye discomfort after continuous reading for 20 minutes with a smartphone (Antona et al., 2018).

In the present study, the most reported eye symptoms were the sensation of the eye. Eyestrain symptoms in 18 young adults performing a 60-min reading task on a smartphone have been assessed and increased eyestrain symptoms after reading correlated with a decrease in viewing distance (Long et al., 2017). A previous study found that participants' visual fatigue was significantly lower in the dark mode than in the light mode (Kim, K et al., 2019) The light mode with dark letters on a white background makes the display emits high luminance that leads to visual fatigue. A study was conducted to investigate visual fatigue at two different levels of screen luminance and two different levels of ambient lighting, which has found that visual fatigue increases when reading under high levels of screen luminance (Benedetto et al., 2014). Higher levels of light intensity are typically associated with less blinking and a faster rate of tears evaporation that contribute to dry eyes which is one of the main factors of visual fatigue (Benedetto et al., 2013).

6.0 Conclusion, Limitations & Recommendations

In conclusion, the amplitude of accommodation (AA) reduced after 30 minutes of reading with both polarities. In terms of visual fatigue, both polarities caused significant eyestrain. Nevertheless, there was no correlation between objective (post-AA) and subjective (post- VF questionnaire) found. They are several limitations in this study that must be acknowledged. Firstly, the room's illumination may significantly impact the participant's AA and visual fatigue even though the ambient illuminance is set at 200lux. Secondly, the participants in this study were limited to students between the ages of 20 to 25, and the accommodation and visual fatigue might differ from other ages. Therefore, in further study, participants of various ages should be selected to verify this conclusion. In addition, it would be interesting to incorporate colour into the different polarity to compare the visual performance further.

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Paper Contribution to Related Field of Study

This study's information and findings benefited readers, particularly those who frequently use gadgets, by allowing them to modify the display polarity to improve their vision when using mobile phones or tablets. To give a better visual experience for users, this study also presents suggestions for suitable display polarity for electronic device or application designers. This information will help designers and manufacturers improve the quality of visual displays.

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