

## The Comparison of the Effects of Invisible Flicker to Visible Flicker Light-Emitting Diodes (LED) Desk Lamp on Asthenopia

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### Abstract

**Introduction and Objective:** Asthenopia defined as a sensation of visual fatigue, eye weakness, or eyestrain. It is frequently associated with situations where the accommodation and vergence process are more intense such as reading and writing. Asthenopia can be caused by flickering stimuli. Light-Emitting Diodes (LED) can produce flicker. The objective of this study is to compare the effect of invisible flicker LED desk lamp to visible flicker on asthenopia in college student at the library room.

**Methods:** This randomized, double blind, cross over clinical trial compared the asthenopia symptoms and to compared changes in the near point convergence (NPC), accommodative facility (AF) in subjects after doing 90 minutes visual demanding task using invisible flicker LED desk lamp and visible flicker LED desk lamp, with a 1 day break between crossover. Asthenopia assessment is done subjectively by questionnaire, and measured accommodation using flipper lenses and Royal Air Force (RAF) Ruler to assess the near point convergence objectively.

**Results:** In 44 subjects, there were no difference in the proportion of asthenopia and changes in the value of AF between 2 groups. There was a significant difference in NPC changes before and after intervention (invisible flicker: 0.67 (-2.17 - 5.08) cm; compare to that of visible flicker: 1.41 (-1.67 - 12) cm,  $p = 0.006$ ). Burning eyes sensation was more common in invisible flicker LED users.

**Conclusion:** This study shows that the use of invisible flicker LED desk lamp minimize NPC changes after intervention for 90 minutes.

**Keywords:** Asthenopia; Invisible Flicker; Light-Emitting Diodes; Visible Flicker

### Introduction

Asthenopia defined as a sensation of visual fatigue, eye weakness, or eyestrain. It is frequently associated with situations where the accommodation and vergence process are more intense, such as in those who work long periods looking at near distance for example reading and writing [1,2]. Sheedy, *et al.* [3] divided asthenopic symptoms into two major categories, external symptoms (burning eyes sensation, irritation, dry eyes, watery) and internal symptoms (tired eyes, headache, eye pain, diplopia, blurred vision). Asthenopia can be assessed subjectively with questionnaire and accommodative facility (AF) measurement with flipper lenses and can be assessed objectively with near point convergence (NPC) measurement using Royal Air Forces (RAF) Ruler [4].

Asthenopia can be caused by flickering stimuli [5-7]. Flicker is a rapid and repeated change over time in the brightness of light. Visible flicker is flicker that is consciously perceivable by a human viewer. Invisible flicker is flicker that is not consciously perceivable by a human viewer [8]. Nearly all light sources produced flicker includes Light Emitting Diodes (LED) [9]. Light Emitting Diodes (LED) lighting has many benefits over the more traditional lighting technologies, in term of low energy costs, longer life time, more ecologically friendly [10].

Asthenopia has become a significant health problem. In Indonesia, Yoserizal, *et al.* [3] reported the prevalence of asthenopia as many as 50% employee who work with computers more than 2 hours/day. Others study found as many as 57-69% of college students experience asthenopia symptoms [11,12]. Moreover, until recently little information is available regarding the asthenopia among the college student. This study was conducted to compare asthenopia symptoms, NPC and AF changes after working with invisible and visible flicker LED desk lamp among college student in the library room.

### Methods

This study was performed in the library room of STEI University, Jakarta during May to July 2018. The subjects were recruited with the inclusion criteria of male and female college students with a range between 18 and 25 years of age, good ocular examination with presenting vision of 6/6, orthophoria (no shifting found during the cover test) and Body Mass Index (BMI) with a range between 18 and 24.9. The subjects who have dry eyes, myopia and hypermetropia more than 6.00 D and subjects with inappropriate spectacle correction were excluded.

The design of this study was double blind clinical trial with crossover; the subject was taken consecutively. Randomization was use to determined the type of LED lamp that be used in the first attempt of task. Subjects and examiner was masked to the type of LED lamp.

The Health Research Ethics Committee of the Faculty of Medicine, University of Indonesia had approved this study. Informed consent was obtained from all subjects after explaining the study procedures and the effects that may result.

Subjects were randomized to perform visual demanding task on a wood cubicle desk using invisible or visible flicker LED desk lamps for 90 minutes. The mean level of illumination lamp was 422 Lux. Room temperature was 21 - 25°C with level humidity was 40 - 60%. Both lamps were installed into the same desk lamp with the same height and angle to hide the type of the lamp. These lamps are invisible flicker LED lamps ( $Pst^{LM} < 0.5$  and flicker cannot be detect using handphone with the resolution of 640 - 2436 x 750 - 1136 pixel) and visible flicker ( $Pst^{LM} > 0.5$  and flicker can be detect using handphone with the resolution of 640 - 2436 x 750 - 1136 pixel). Before and after doing the visual demanding task, the subjects were measured their near point convergence and accommodative facility.

Near point convergence was assessed With RAF Ruler. The RAF Ruler was placed just above the nose at the brow between the two eyes. The target was moved toward the subject. Near point convergence value were recorded, if there was a subjective report of diplopia (in cm).

Accommodative facility was examined with +2.00 D flipper lens. The subjects focus through one pair of lenses at an object at near distance (40 cm). When the object is clearly focused, a flip is quickly performed to the other lens pair and the subject focuses through them. This was recorded as 1 cycle. The examination repeated until 1 minute (1 cycle per minute).

After completion of work, the subjects filled out questionnaires of asthenopia. The 15 items questions were eye fatigue, pain, heaviness, unfocus, blurred, double vision, burning, watery eyes, dry eyes, foreign body sensation, itchy, heavy eyelid, sensitive to bright light, change in sensation of seeing color and headache. The score for the 15 questions based on Visual Analogue Score. The total score was given to each subject ranged from 0 - 150. Subjects were considered to be asthenopia if each question had VAS > 2 or if their total score was > 30.

The subjects took a rest for 1 day. After that, the subject had to work with the other LED lamp.

**Results**

The total number of subjects who were willing to participate in this study was 100 subjects, of whom 50 subjects did not meet the inclusion criteria, for the following reason: 31 subjects had refractive error and did not want to use glasses, 10 subjects had presenting vision less than 6/6 and 9 subjects had higher BMI than 24.9 or lower than 18. Six subjects had dry eyes. Forty four college students aged 18 - 24 years were recruited for this study. All subjects had a visual acuity of 6/6 in both eyes. No one had ocular abnormalities.

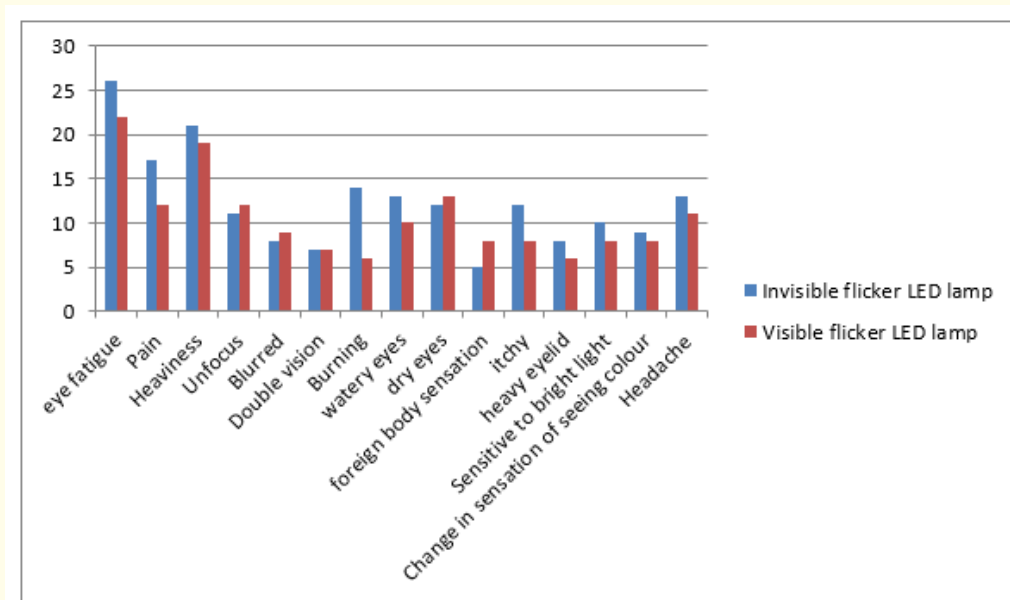
This study showed, there were no statistically significant differences in the proportions of asthenopia on both group (p = 0.68), as given in table 1.

		Visible flicker		Total	P
		Yes	No		
Invisible	Yes	11 (25)	4 (9%)	15 (34%)	0.68*
	No	2 (5%)	27 (61%)	29 (66%)	
Total		13 (30%)	31 (70%)	44 (100%)	

**Table 1:** Comparison of asthenopia in both groups (n = 44).

\*: McNemar test.

McNemar’s analysis of each asthenopia symptoms was performed, and there were no statistically significant differences (p > 0.05) between the two groups. Invisible flicker LED lamp had a higher result in the complaint of burning eye sensation and was significantly different than the visible LED lamp group (p = 0.008), as given in figure 1.



**Figure 1:** Invisible flicker and visible flicker LED lamp graph questionnaire.

This study showed, there were statistically significant differences in NPC changes between invisible flicker and visible flicker LED lamp ( $p = 0.006$ ), as given table 2.

On the accommodative facility value before and after intervention (Table 2), there were no statistically significant differences in both groups ( $p = 0.649$ ).

Variable	LED		P
	Invisible	Visible	
<b>Near Point Convergence (cm)</b>			
Before	8.31 ± 1.35	8.20 ± 1.49	0.563
After	8.62 (6 - 14.75)	9.25 (6 - 20)	0.014*
Δ	0.67 (-2.17 - 5.08)	1.41(-1.67 - 12)	0.006*
<b>Accommodative facility (cpm)</b>			
Before	17.11 ± 4.01	16.37 ± 4.60	0.245
After	17 ± 4.15	16.26 ± 4.37	0.170
Δ	-0.11 ± 1.45	0 (-6-4)	0.649

**Table 2:** Comparison of near point convergence and accommodative facility in both group.

\*: Significant with Wilcoxon test

cm: Centimeter, cpm: Cycle Per Minute.

## Discussion

In this study, the proportion of asthenopia was statistically no significant differences in both groups, although each group has different symptoms. This may be because of both groups have a  $Pst^{LM}$  flicker value < 1, where the  $Pst^{LM}$  value < 1 can still be tolerated [13,14].

Asthenopia in this study was assessed subjectively through questionnaire. At present, there are various kinds of questionnaires regarding asthenopia, but until now there is no standard questionnaire of asthenopia. This study used Yoserizal., *et al.* [4] questionnaire's, which contains 15 questions about asthenopia symptoms, and answers based on the Visual Analogue Score (VAS) Score. Questionnaire using VAS was also used by Abdi., *et al.* [15] study. Meanwhile a simpler questionnaire was used by Eko., *et al.* [16] study, which contains 6 questions about symptoms of asthenopia. Subject was considered asthenopia if one of the questions was answered yes. Cohen., *et al.* [17] study used a questionnaire which contains 8 questions about the symptoms of asthenopia based on the answer; never, sometimes and often.

Burning eye sensation was more likely in the invisible flicker LED lamp. This complaint may be caused by the presence of a higher brightness value in the invisible flicker LED light compared to visible flicker. This burning eye sensation was associated with dry eye [18].

Flicker can affect the occurrence of asthenopia in both types, internal and external. Flicker can degrades the quality of the image being viewed. To overcome this condition, there is a squint movement. Squint can increased the orbicularis oculi muscle contractions and reduced blink rates. In this condition, dry eyes symptom may occur [3,18].

The most common complaint in both groups was fatigue. Fatigue and eye heaviness can arise due to increased contraction of the orbicularis oculi muscle. This might be caused by glare on both groups. Glare can cause an increasing in electrical electromyography (EMG) activity in the orbicularis muscle orbital part oculi [19]. Fatigue was also the most common asthenopia symptoms in Yoserizal., *et al.* [3] study. Glare and light reflection on the monitor screen Video Display Terminal (VDT) are the main cause of asthenopia on computer users [2,3].

The LED system creates a high intensity of light from a small transmitter area, therefore LED lights can cause glare. Sheedy, *et al.* [2] showed that asthenopia can also be caused by glare. Glare can be reduced in several ways, such as avoiding a very bright light, keeping the line of the light source away from the line of sight, reducing reflector material around the light source and keeping a small luminance difference between the light source and the background of the light source [20]. In this study, glare was tried to reduce by using desk lamp in both groups. By using a desk lamp, subjects can avoid looking directly at the light source, thereby reducing glare [5].

Poor sitting posture also affects muscle fatigue and pain in the neck and shoulders. One of the ergonomics factors is a comfortable chair with adjustable height [20]. In this study, it is difficult to maintain the subject's position in the same position for 90 minutes, so the subject can unwittingly change his sitting position and cause changes in the position of the eye line to the lamp source which will cause glare.

The cubicle desk used in this study was made of wood and painted using varnish so that the desk looks shiny. This causes light reflection from the lamp and cause glare [21].

This study showed that near activity for 90 minutes can cause 15 subjects (34.1%) in the invisible flicker LED lamp group and 13 subjects (29.5%) in visible LED lamp group complain of asthenopia. Meanwhile, Guerrero, *et al.* [5] study showed 35 minutes of near activity can cause asthenopia. Other studies showed a different minimal time of near activity that may cause asthenopia [3,4].

The incidence of asthenopia in this study was smaller than previous studies, although in this study the intervention time was longer than other studies. This can be caused by several possibilities such as strict criteria inclusion for subjects, arrangement of rooms with good illumination and regulation of air humidity. This arrangement reduce confounding factor that may caused asthenopia. The difference in the examination method also made the results of this study different from previous studies.

Dry eyes symptom was also a common complain in this study. Dry eyes can be caused by an irritation sensation from the exposed ocular surface. Reduced blink rate has also been shown while reading a book (10 blinks/minute) compared to when looking at the picture (16 blinks/minute). Blinking will interfere the entry of incoming visual information while reading. Therefore the mechanism of blink is blocked [14].

Dry eyes symptom also arise in workers who use VDT. A larger exposed area when viewing a computer display results in considerably greater evaporation, causes dry eyes symptom [3].

The change in the NPC value using the invisible flicker LED is 0.67 cm (range -2.17 to 5.08). This value is smaller and statistically has a significant difference compared to visible flicker LED group, 1.41 cm (range -1.67 to 12 cm). Invisible flicker LED with a smaller change of the NPC value can be interpreted as a better level of comfort. Near point convergence values are needed to determine convergence of insufficiency (CI), where CI is the most common cause of asthenopia [22].

The change of AF value can indicate the presence of asthenopia. Accommodative facility examination was taken with + 2.00 D flipper lens binocularly at near vision. In this study the mean change in AF in both groups did not showed significant differences.

The AF value in this study has a higher value compared to other studies [23]. Accommodative facility value can be influenced by the age of the subject. It has been reported that the older the subject, the lower AF value. Another study stated that AF values at the age of 16 - 25 years were 10 cpm (5.5 - 13) and at ages 26 - 35 years it decreased to 4 cpm (1 - 9) [5,17].

Radhakrisnan, *et al.* [24] study showed, there was no significantly differences in the AF value for near distances in subjects with emetropia and myopia. So, in this study, the patient's refraction status was ignored because it did not affect the AF's ability at near distance. The study by Eko, *et al.* [12] explained that asthenopia was not affected by refractive abnormalities.

In addition, there are several other factors that affect the value of AF, including the time needed by the subject to read the target, the time needed to rotate the lens, saccadic movements, subjective criteria to assess a clear target and eye speed for relaxation and accommodation [18].

The use of a flipper lens can also be used as accommodation training. Study by Sterner, *et al.* [25] explained about accommodative facility training in subjects who had impaired accommodation. Accommodative facility training were carried out using the flipper lens for 3 minutes 5 times a day, minimum of 2 - 5 weeks. This training can eliminate subjective symptoms such as headaches and blurred vision when subjects do near activities.

Psychological factors is one of the confounding factors to AF value and cannot be completely eliminated [26].

This study have superiority compared to others, because we used the actual library room and we tried to make the room as ideal as possible. In addition, this study had a longer intervention time compared to other studies.

The limitation in this study is that we did not measure the proportion between sitting height of the subject and the height of LED desk lamp, to see whether there is glare or not. This was anticipated by measuring the lamp height and angle of the LED desk lamp with the aim of reducing the glare effect.

### Conclusion

This study showed that the use of invisible flicker LED desk lamp minimize NPC changes after intervention for 90 minutes. There were no statistically significant differences between two groups with respect to asthenopia questionnaire and AF value. Invisible flicker LED lamp was more likely to have burning eye sensation. The use of invisible flicker LED lamp is expected to reduce asthenopia condition.

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