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Effect of LED-based Study-Lamp on Visual Functions

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ABSTRACT

Changes in visual functions following near vision tasks under lighting provided by an LED-based study lamp were analysed. Visual performance and basal tear production before and after reading and painting tasks were assessed in the light provided by an LED and a CFL based study lamps on thirty volunteers with normal vision. Measurements were made for each light with room lights on and off. Visual comfort was assessed using a questionnaire. Statistically significant but clinically insignificant changes were seen only in basal tear production in three conditions. Unexplainable changes were seen in the near visual acuity for two contrast levels in certain conditions. No other parameters showed any significant change in any condition.

Keywords

LED lamp, visual functions, Munsell chips, Near vision tasks

INTRODUCTION

Reading is a complex visual process involving visual and environmental variables [19, 9]. The predominant factors that influence reading performance are luminance [13], uniformity of illumination, contrast of the task [8]. Color of the source and/or the target does not affect performance [10, 11, 5]. Berman et al studied the effect of lighting color temperature and luminance on near visual acuity in children and found that higher the color temperature the better the acuity and that lower the luminance the lower the acuity at higher color temperatures [2].

Reading speed and critical print size at which the subject has the maximum reading speed are usually measured with MNRead acuity charts [17]. Reading performance can be improved in illumination levels of 100-300 lux. Age-Related Macular Degeneration (ARMD – an ocular condition which affects the central part of the retina called macula that aids in fine vision) patients are known to prefer yellow filters to improve their reading speed [5]. The reading rates for normally sighted subjects are greatest for a range of intermediate character sizes ranging from 0.3 degree to two degree. Reading speed declines for characters smaller than 0.13 degrees and characters larger than 4 degrees [1].

Traditional incandescent lamps use high amount of energy to produce standard amounts of indoor lighting and also sodium light is known to cause visual fatigue [3] after prolonged reading [12]. Fluorescent (FL), compact fluorescent (CFL) and Light Emitting Diode (LED) light sources use progressively less amounts of energy to energy but directional sources, the visual performance under these light sources could be different. Our aim was to estimate the efficacy of LED lamp for continuous and/or demanding near vision tasks. Therefore we compared the effect of LED based reading lamp and CFL on various visual tasks and also estimated the visual comfort.

METHODS

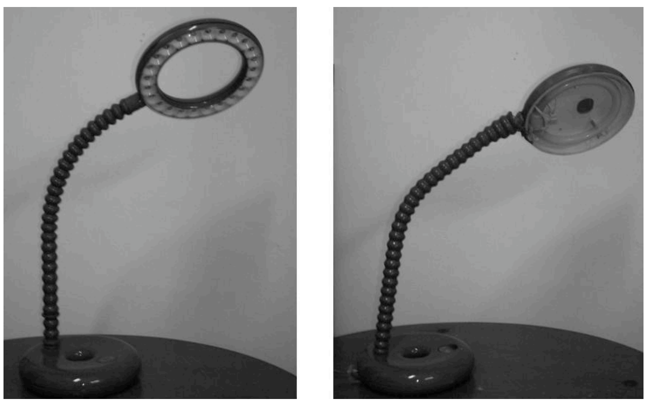
The study adhered to the tenets of Declaration of Helsinki and was approved by the institutional review board (IRB). Signed informed consent was obtained from all subjects. All subjects underwent complete optometric and orthoptic evaluations [4]. These included determination of monocular visual acuity (resolving ability) for distant and near targets, refractive error, action of the eye muscles, alignment of the two eyes (phoria status), ability and speed of shifting gaze from distant to near targets (accommodation amplitude and facility), ability of the two eye to work together for near objects (convergence). In addition, their color vision, stereopsis (ability to perceive depth using the two eyes) and basal tear production were tested. Screening for color vision was done using Ishihara pseudo-isochromatic plates, stereopsis using Wirt circles and basal tear production using Schirmer's test II. Only subjects who met our inclusion criteria were included. The inclusion criteria were:

- Age: 13 – 25 years
- Read and write English at 8 grade level
- Best corrected distance visual acuity – equal to or better than 6/6
- Best corrected near visual acuity – equal to or better than N6
- Near point of accommodation as per Hoffstetter's average formula [6, p70]
- Accommodative facility better than or equal to 10 cycles per minute using $\pm 1.75D$ flippers
- Near point of convergence ≤ 10 cm
- Distance and near Phoria as per Morgan's values [14]
- Basal tear production using Schirmer's Test II $\geq 10mm$
- Stereopsis using Wirt circles - 40 arc sec
- Normal findings in the anterior and posterior segment evaluations

Those who had the following were excluded:

- Severe dry eyes (< 10mm wetting length in Schirmer's test II)
- More than 3 errors in Ishihara pseudoisochromatic plates [6, p105]
- Overaction/underaction of any extraocular muscle
- Any ocular pathologies/diseases

Study Lamps:
The LED based lamp consisted of an array of 24 white LED-s spaced equally on the circumference of a circle of diameter 15 cm (Fig 1a). Figure 2 displays the manufacturer supplied power spectrum of the LEDs used in the lamp. The CFL lamp consisted of a single circular CFL source of the same radius (Fig 1b). We were not able to get the power spectrum of the CFL from the manufacturers nor did we have the facility to measure the same. However, spectral power distribution of common fluorescent light sources could be easily found on the internet [20]. Figure 3 shows the primary and secondary task areas as defined in the study. Uniformity index was calculated as the ratio of the illuminance of the light falling at the boundary between the primary and secondary task area and the illuminance at the center of the primary task area.



(a) (b)

Figure 1: (a): The LED based light study lamp; (b): CFL study lamp. For description refer text.

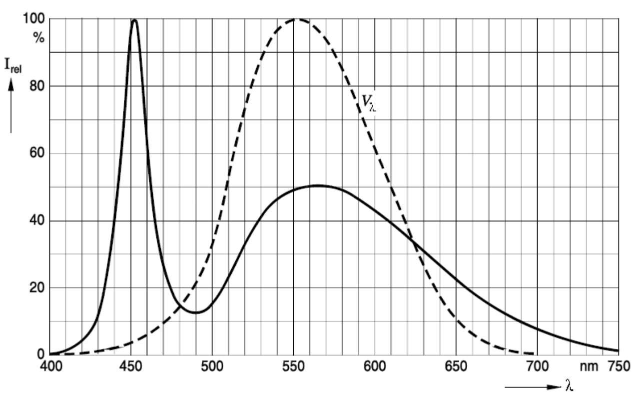


Figure 2: The dark continuous line in the upper figure denotes the relative spectral power distribution of the LED used in the LED based study lamp. The dashed curve denote the human photopic sensitivity function, commonly known as the V(λ) curve. The graph was supplied by the manufacturer of the LEDs.

Study area:
A standard study table and chair was placed in the middle of a windowless room that measured 4.2 m x 4.2 m x 3.1 m. Since all subjects who participated in the study were right handed, the study lamp was placed on the left side of the table so that light from the lamp illuminated the center of the table. The subjects were allowed to adjust the position of the lamp. The subjects were instructed to keep the task materials where the maximum light was falling on the table, i.e., on the primary task area. A video camera focused on the face of the subject was placed without obstructing the light falling on the task area. Two fluorescent lamps fitted on the ceiling directly above the reading table provided illumination of approximately 200 lux on the table.

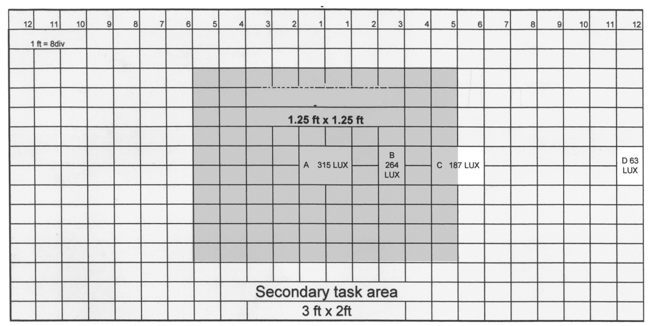


Figure 3: Primary and secondary task areas defined in the study. The shaded portion is the primary task area and the non-shaded portion is the secondary task area. The primary task area measured 1.25 ft x 1.25 ft and the secondary task area measured 3ft (length) x 2 feet (depth). Area outside the secondary task area is known as the tertiary task area and it is not depicted in the figure.

Experiment:
In an attempt to study the interaction of the study light with the environmental lighting, the experiments were done under four different lighting conditions as shown in table 1.

Table 1: Definition of the four conditions used in this study

Condition name*	Room lights	Lamp used
I	On	CFL lamp
II	Off	CFL lamp
III	On	LED lamp
IV	Off	LED lamp

*Conditions II and IV were called "Dark Conditions" since the room lights were off. Similarly, conditions I and III were called "Light Conditions".

During each condition, the same set of experimental procedures was performed. The procedures were done in the following order: (i) ten minutes of adaptation to the lighting condition – the standard and LED lamps were kept on and only the room lights were switched either on or off, (ii) evaluation of basal tear function using Schirmer's strip, (iii) achromatic point estimation using Munsell chips, (iv) Near visual acuity at various contrast levels using a Landolt-C based near vision chart, (v) stereopsis estimation based on Wirt circles, (vi) reading speed measurement using variations of MNREAD chart (which we named SNREAD, to avoid confusion with MNREAD), (vii) reading task for ten minutes, (viii) coloring task for ten minutes, (ix) procedures (ii), (iv) and (v) mentioned above (post-task measurements), and (x) administration of a five-point Likert scale questionnaire. Procedures (vi), (vii) and (viii) (i.e., reading speed measurement with SNREAD charts, reading and paining tasks) were video recorded to extract the reading speed, critical print size and blink rate.

Basal Tear Production:

Basal tear function is a measure of normal production of tears and hence is also a measure of dry eyes. It is usually quantified using Schirmer's test II. This test uses a thin strip of Whatman filter paper #40 called the Schirmer's strip. The Schirmer's strip is 5mm x 35mm in dimension and has graduations along its length at every millimeter. The subject's eye is anesthetized using a single drop of proparacaine 0.5%. The Schirmer's tear strip is inserted into the temporal part of the lower cul-de-sac (the area under the lower eye lid) in both the eyes. The strip remains in the eye for 5 minutes. Due to capillary action, the tear from the eye wets the Schirmer's strip. The wetting length at the end of 5 minutes is noted. If the wetting length is 15 mm or more, the tear production is considered as normal. Wetting lengths less than 10 mm are considered indicative of severe dry eyes. Basal tear production was measured using Schirmer's test II before and after the reading and painting tasks in each condition. The Schirmer's test II is conventionally done only with room lights turned off. But in our experiment it was done under the lighting provided for each condition to study the effect of the light on tear production.

Achromatic Point Estimation:

Achromatic setting was measured using 40 plates of Munsell chips. Achromatic point as defined by Werner et al (1993) is "Typically called the white point, … more accurately called the achromatic point, as it may appear dark gray, light gray or white, depending upon its luminance and surrounding conditions of illumination" [18]. Each plate consisted of 7 chips that varied from one hue to its opponent hue and arranged randomly on the plate. Of the 7 chips, one would be achromatic. The task would be to identify the chip that looks "hueless" or "colourless" or "the chip that is devoid of the hues in the opponent axes of that particular plate". A practice session was given using few randomly chosen plates. The response was recorded in the scoring sheet that accompanies the Munsell chips. Each chip has a score attached to it ranging from -3 to +3 with 0 denoting the achromatic point and values closer to zero denoting chromaticities closer to the achromatic point on that axis. For our experiment, we only noted the number of errors made in the 40 plates irrespective of the direction on error. We did this because we were interested how the different lighting conditions affected this task.

Near Visual Acuity at Various Contrast Levels:

Near vision acuity was measured using a variation of the VALiD kit [16]. To avoid confusion with VALiD kit we called our chart the SVIS chart (Fig 4). The SVIS chart was designed for use at 40 cm. The chart was constructed using the Landolt-C optotypes facing up, down, right and left. The chart contained ten sets of three rows of C-s. Orientations of C-s were randomized using the pseudorandom number generator in Microsoft Excel. Each row contained C-s of various sizes that decreased from 1.0 logMAR to -0.3 logMAR in steps of 0.1 logMAR. Each set of C-s had a fixed contrast value. The contrast decreased from 100% to 4% in steps of 0.15 log units down the chart. The chart was placed in the primary task area such that the light from lamp under consideration fell on the chart. The subject was instructed to speak aloud the orientation of the C from the top-most line. At any contrast level, the acuity will be the smallest size of C that was correctly identified. Each subject was asked to read only one of the three lines at each contrast level. For each contrast level, the visual acuity was thus noted. We use the term visual acuity to mean visual acuity at 100% contrast. For all other contrasts, we mention the contrast value.

Stereopsis:

Stereopsis is the ability to perceive depth using the two eyes together. We measured stereopsis using Wirt circles illuminated by the lighting of the given condition. In this procedure the subject will be asked to wear a polarizing spectacle and asked to view a polarizing sheet. The polarizing sheet contains groups of four circles. In each group one circle will appear to float above the rest at some distance. The subject's task is to point out the floating circle. This distance is given in terms of what is called the retinal disparity measured in arc seconds. Because of the laterality of the two eyes, the image on the retinae of two eyes will be slightly laterally displayed. This is known as retinal disparity [7]. Wirt circles are useful for measuring stereopsis from 800 arc seconds and 40 arc seconds.

Reading Speed Estimation:

Reading speed was calculated using the SNREAD chart. SNREAD is a variation of the MNREAD near vision reading chart that contains eleven lines of continuous text. Each line has 60 characters and the size of the lines decreased down the chart. There are two versions of the chart that are available. We constructed 12 versions of the chart. These charts were called SNREAD chart. The SNREAD charts had the same construction design as the MNREAD chart, but the sentences in these charts were different. The sentences used in these charts were selected from books recommended for 8th grade students. Essentially designed for use at 40 cm, the chart was placed in the primary task area illuminated using the lamp. The same version of the chart was not given to a subject more than once. The subjects were asked to read the chart aloud clearly with minimum mistakes. Video recording of the procedures was started at this point. Reading errors and reading time was calculated from the recording. The lines in the chart vary in size from 4.0M to 0.4M. M notation is a metric measure of the Visual Acuity. Each mm of letter height is set equal to 0.7M. The measurement is done with lower case letters without any ascending or descending limb, such as e, o and c. If the visual acuity is 1M it means that the letter subtends 5 arc minutes at a distance of 1 m.

Reading Task:

The subject was given a reading task for ten minutes. The reading material was kept at their habitual working distance. The subjects were instructed to read at their usual reading speed. The text in the reading material was printed in 8 point Times New Roman font with 1.5 line spacing. The contents of the reading task varied across experimental conditions. All reading materials had a side box that highlighted the salient point of the material. This highlight was printed in 10 pt Times New Roman.

Colouring Task:

A set of drawings were chosen from a collection of colouring book. One of the investigators coloured a randomly chosen drawing with crayons and the subject was asked to colour another copy of the same drawing with this as the template. The crayon set that was used had totally 36 shades. Hue variations were quite small and not easy to make out. For example, shades in green varied as "Olive green", "Emerald green", "Deep green", "Virdian hue", "Light green" and "green". Subjective responses for the shades that were difficult to match were noted. The same crayon set that was used by the investigator to colour the template was given to the subjects for the colouring task too. This was done for ten minutes. If the subject finished the task within ten minutes, a new drawing was given to be completed in the remaining time.

Blink Rate:

Blink rate was calculated from the video recording when the reading and coloring tasks were in progress. The total number of blinks over the period of 20 minutes was determined and from that the number of blinks per minute was calculated.

Questionnaire:

The questionnaire aimed to assess visual discomfort during various tasks. At the end of each experimental condition, a 5-point Likert scale questionnaire was given to the subjects to fill out. This questionnaire had 14 questions six of which dealt with visual comfort (such as glare, eye strain, dry eyes, eye fatigue, eye pain and headache) and the remaining eight were fillers (such as hunger, back ache, anxiety, questions from the text given for reading and painting, etc). From the responses, the visual discomfort score was calculated [3].

Other Procedures:

The order of the conditions was randomized for each subject. Different versions of the same chart were used for different experimental conditions for both reading speed and visual acuity measurements. The contents of the reading task and objects for the coloring task were varied across experimental conditions. Not more than three sessions per day were done for each subject. Minimum of half-hour breaks were given between conditions.

Analysis:

Changes in visual functions in a single condition before and after the reading and painting tasks were analysed. These are variously called "within condition changes" or "pre-post changes" or just "changes". Differences in these changes across lighting conditions were also analyzed. Unless stated otherwise, all comparisons were done using Wilcoxon signed-rank test. Results were considered significant when $p < 0.05$. All analysis was done using SPSS 15, MATLAB 7.2 and Microsoft Excel.

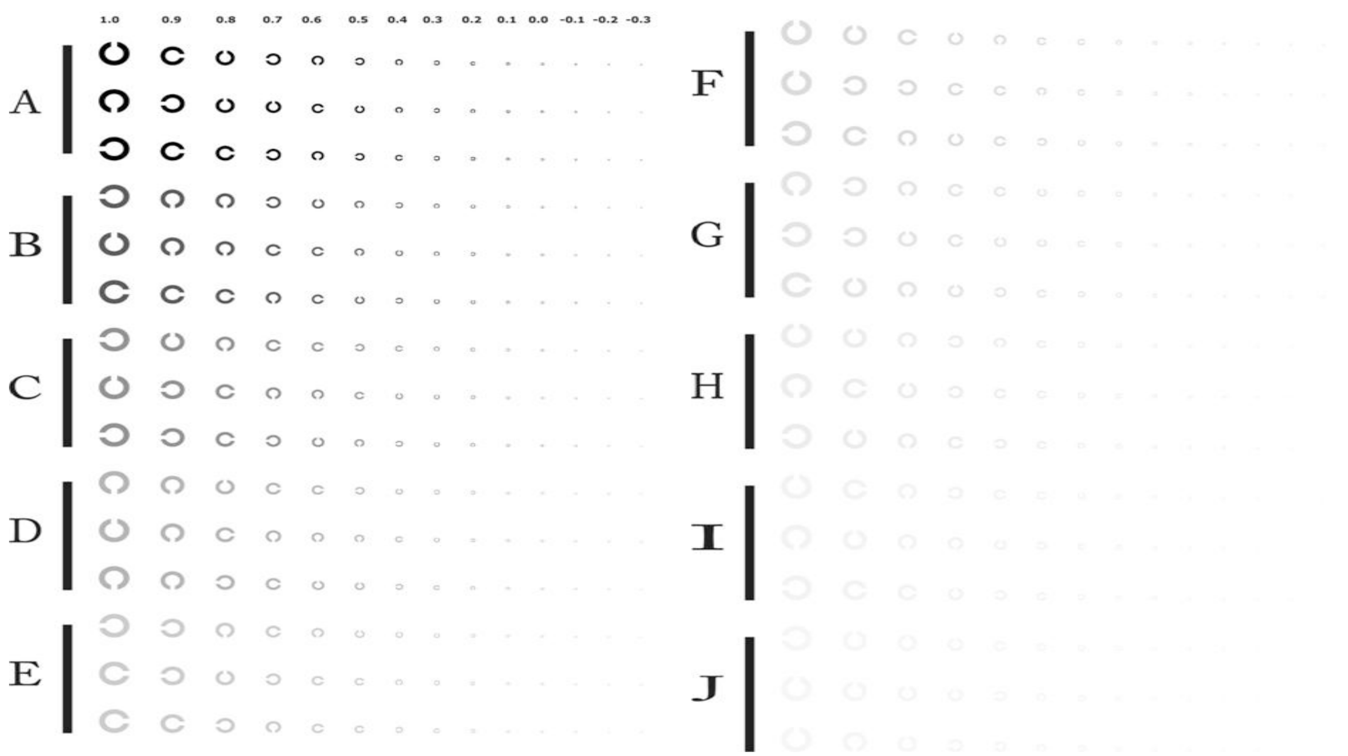


Figure 4: SVIS chart. The contrast varies after every three rows. All the letters in a given triplet have the same contrast. The contrast values were: A-100%; B-71%; C-50%; D-35%; E-25%; F-18%; G-13%; H-9%; I-6%; J-4%. The acuity level varies along the row of every line in every triplet in steps of 0.1 logMAR starting from 1.0 logMAR to -0.3 logMAR. The chart is designed for use at 40 cm reading distance

RESULTS

The illuminance values due to the LED lamp alone in the primary task area for various subjects were around 200 lux and with the CFL lamp the value was around 500 lux. The uniformity index was found to be 0.73 for the LED lamp and 0.50 for the CFL lamp.

Thirty subjects participated in the experiments. The number of subjects, however, for following variables was reduced as given in parenthesis: Visual Discomfort Score (29); Blink Rate (20); Reading Speed (26); Critical Print Size (26). The reduction in numbers was due to either incomplete response or failure of video recording. All subjects were college students, doing their undergraduate or postgraduate studies. The age of the students ranged from 18 to 23.5 years. There were 25 female subjects and 5 male subjects who participated in the study.

Changes Within a Condition:

Basal Tear Production:

The mean changes in tear production in various conditions are shown in fig 5. Clinically, changes in Schirmer's test are said to be significant when the difference between two readings is 5mm or more. In condition I, the change was found to be statistically insignificant (mean change; 0.65 mm; p=0.45). In condition II (mean change = 1.75 mm; p=0.01), III (mean change = 2.13 mm; p=0.01) and IV (mean change = 2.12 mm; p=0.01) though statistically significant changes were found, these changes were clinically insignificant. The maximal mean change was 2.13 mm in the third condition. The median changes in all these four conditions were 0 mm.

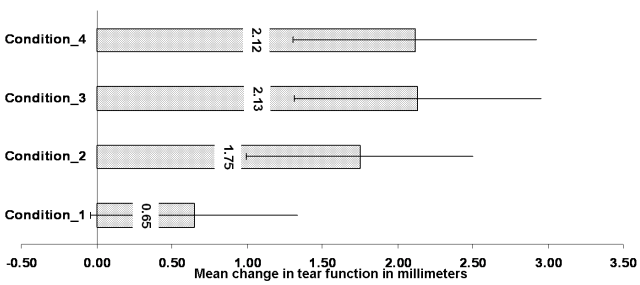


Figure 5: Mean change in basal tear production in the four conditions. The boxes denote the mean values and the lines denote ± 1 std error of means.

Near Visual Acuity at Various Contrast Levels:

The changes in the near visual acuity at various contrast levels for the four conditions are shown in table 2. As can be seen, most changes were statistically insignificant. Only the changes for condition IV (i.e., LED lamp on with the room lights turned off) at contrast values of 13% and 9% were statistically significant. Since there is no a priori reason why only these should be statistically significant changes, we propose that these changes are spurious in nature.

Stereopsis:

All subjects had zero change in stereopsis in all the four conditions and hence we did not do any statistical analysis on this parameter.

Differences Across Conditions:

Comparison of changes in conditions I and III was done to study the behavior of LED lamp as compared to the CFL lamp in a bright environment and between II and IV to study the same in a dark environment. Analysis between conditions I and II was done to understand the effect of the room lighting on the CFL lamp; similarly, comparison of changes in conditions III and IV was done to find the effect of external illumination on the LED lamp.

Table 2: Changes in near visual acuity across four conditions

Contrast (%)	Condition	Mean	Median	p – value
100	I	-0.04	0.00	0.10
	II	0.02	0.00	0.20
	III	0.02	0.00	0.48
	IV	0.03	0.00	0.10
71	I	-0.02	0.00	0.18
	II	0.00	0.00	0.68
	III	0.00	0.00	0.84
	IV	0.00	0.00	1.00
50	I	0.01	0.00	0.43
	II	-0.02	0.00	0.40
	III	0.03	0.00	0.19
	IV	-0.01	0.00	0.55
35	I	0.01	0.00	0.62
	II	0.01	0.00	0.49
	III	-0.01	0.00	0.82
	IV	0.03	0.00	0.13
25	I	0.00	0.00	0.98
	II	0.02	0.00	0.20
	III	-0.01	0.00	0.85
	IV	0.02	0.00	0.51
18	I	0.02	0.00	0.24
	II	0.00	0.00	0.78
	III	0.03	0.00	0.18
	IV	-0.01	0.00	0.78
13	I	0.04	0.00	0.09
	II	0.01	0.00	0.98
	III	0.01	0.00	0.56
	IV	***0.04***	***0.00***	***0.03***
9	I	-0.03	0.05	0.18
	II	0.03	0.00	0.16
	III	0.02	0.00	0.32
	IV	***0.05***	***0.00***	***0.01***
6	I	0.02	0.00	0.51
	II	0.04	0.00	0.07
	III	0.02	0.00	0.30
	IV	0.02	0.00	0.38
4	I	-.06	0.00	0.47
	II	0.02	0.00	0.42
	III	-0.03	0.00	0.22
	IV	0.00	0.00	0.86

Near Visual Acuity at Various Contrast Levels:

The differences in near visual acuity at various contrast levels across conditions are shown in the table 4. As can be seen most differences are statistically insignificant. Significant differences were seen only between conditions I and III at 100 % contrast and between conditions I and II at 9 % contrast. The first difference could be indicative of a real difference in the light provided by the two lamps when the room lights were kept on. However, the difference between conditions I and II at 9% contrasts level has no rationale to be believed. Moreover, the differences were only 0.05 logMAR which is clinically insignificant.

Basal Tear Production:

Differences in changes in tear production across the various conditions were found to be statistically insignificant (table 3). Since the maximal mean change was 2.13 mm in the third condition, these differences across conditions were neither clinically significant. The median difference value was found to be 0 mm for all the four comparisons.

Table 3: Change in basal tear production across conditions.

Conditions compared	Mean Difference (mm)	p-value
I and III	-1.48	0.13
II and IV	-0.37	0.79
I and II	-1.10	0.09
III and IV	0.02	0.57

Stereopsis:

The amount of change in depth perception (stereopsis) in each of the lighting condition is 0 arc seconds. Therefore the amount of change across lighting conditions was of no difference.

Achromatic Point Estimation:

Mean error scores were 3.66 (± 3.85), 3.5 (± 4.14), 5.33 (±5.83), and 5.2 (± 4.77) for conditions I, II, III, and IV respectively. Under the LED lamp, the average error scores were around 5 irrespective of whether the room lights were kept on or off, while it was around 4 for the CFL lamp. Comparison of error values in achromatic point estimation using the Munsell chips across the four conditions are shown in figure 6. None of the differences were found to be statistically significant (p > 0.05 for all the four comparisons). Since there is no standard for clinical usage of achromatic setting we cannot comment about the clinical significance of the differences. However, we surmise that the differences are clinically insignificant since the magnitude of difference is only about 1.5 out of 40 plate which translates to an error rate difference of 3.75%.

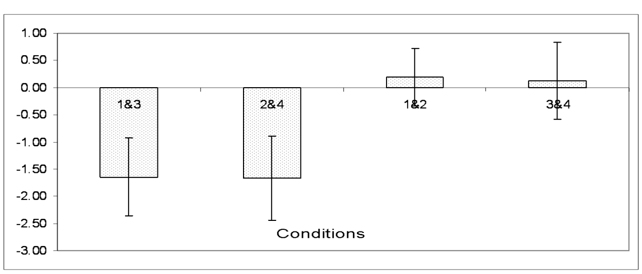


Figure 6: Mean differences in error scores in Munsell colour chips across various conditions.

Table 4: Difference in changes in visual acuity at various contrast levels compared across various conditions

Contrast (%)	Conditions compared	Mean	Median	p - value
100	I and III	**-0.05**	**-0.10**	**0.05**
	II and IV	-0.01	0.00	0.39
	I and II	-0.05	-0.05	0.08
	III and IV	-0.01	0.00	0.52
71	I and III	-0.02	0.00	0.39
	II and IV	0.01	0.00	0.70
	I and II	-0.03	0.00	0.22
	III and IV	0.00	0.00	0.71
50	I and III	-0.01	0.00	0.82
	II and IV	-0.01	0.00	0.83
	I and II	0.04	0.00	0.11
	III and IV	0.04	0.00	0.35
35	I and III	0.01	0.00	0.61
	II and IV	-0.02	0.00	0.62
	I and II	-0.01	0.00	0.75
	III and IV	-0.04	0.00	0.18
25	I and III	0.01	0.00	0.88
	II and IV	0.01	0.00	0.92
	I and II	-0.02	0.00	0.48
	III and IV	-0.02	0.00	0.55
18	I and III	-0.01	0.00	0.59
	II and IV	0.00	0.00	0.93
	I and II	0.02	0.00	0.32
	III and IV	0.04	0.00	0.23
13	I and III	0.03	0.00	0.39
	II and IV	-0.03	0.00	0.21
	I and II	0.03	0.00	0.27
	III and IV	-0.03	0.00	0.21
9	I and III	-0.04	0.00	0.09
	II and IV	-0.02	0.00	0.37
	I and II	**-0.05**	**-0.05**	**0.03**
	III and IV	-0.03	0.00	0.26
6	I and III	-0.01	0.00	0.78
	II and IV	0.02	0.00	0.43
	I and II	-0.02	-0.10	0.51
	III and IV	0.00	0.00	0.93
4	I and III	-0.04	0.00	0.74
	II and IV	0.02	0.00	0.64
	I and II	-0.08	0.00	0.35
	III and IV	-0.02	0.00	0.41

Maximum Reading Speed and Critical Print Size:

Maximum reading speed (MRS) measured as number of words correctly read per minute and critical print sizes (CPS – critical print size is one acuity level above the size at which the maximum reading speed was obtained) were estimated using recommended methods. Comparison of these two quantities across the four conditions revealed no statistically significant differences (table 5) except for critical print size when compared between conditions II and IV; even this was only of marginal significance. Both of these conditions are “Dark conditions”. We hypothesize that the light provided by the LED lamp was such that better reading performance was obtained with larger print sizes when using CFL lamp. This is justified by the illuminances provided by the two lamps. A plot of reading speed against font size did not come up as an inverted U for all subjects.

Table 5: Maximum Reading speed and critical print size on comparing between various conditions

Conditions compared	MRS difference (wpm)		CPS (logMAR)	
	Mean	p-value	Mean	p-value
I and III	3	0.92	-0.1	0.74
II and IV	-10	0.10	-0.2	0.05
I and II	6	0.33	0.0	0.24
III and IV	-7	0.27	0.1	0.94

Blink rate:

Blink rate was reduced from normal across all condition and had a value of around 5 per minute. None of the comparisons across conditions showed any significant difference.

Visual Discomfort Score:

Visual discomfort score was obtained using Rasch analysis. Different weights were given for each of the visual comfort variable. The response to a given question had values ranging from 0 to 5. For each question, the answer was multiplied by the weight for that question and these were summed to get the total score. Maximum score (14 out of 85) was obtained for condition 3. Most people responded ‘no discomfort’ for all the tested parameters, namely, fatigue, pain, glare, headache, eyestrain and dryness. Among those who had discomfort, glare was the most common visual discomfort across all conditions. Comparison of visual discomfort score across conditions revealed no significant difference.

LED – CFL Comparison: Pooled Analysis:

Since we did not find substantial differences in the visual performance under the two lamps under the two lighting conditions, we decided to pool date from the two lighting conditions for each of the lamps to see any difference in these two lamps. Statistically significant differences in changes were seen in the visual acuity at 100% contrast using the SVIS chart. Under the CFL lamp, the visual acuity improved by 0.02 logMAR unit and deteriorated by 0.01 logMAR unit under the LED lamp. However, both these values are way too small compared to be of any clinical significance. The only other parameter that showed any statistically significant difference between the two lamps was the achromatic point setting. The mean setting for the CFL lamp was 3.58 and 5.27 for the LED lamp. These translate to an error rate of 8.95% for the CFL lamp and 13.18% for the LED lamp.

DISCUSSION AND CONCLUSION:

Statistically significant change was not seen in most of the visual/ocular parameters tested. Where statistically significant change was seen, the magnitude of change was not clinically significant. Basal tear secretion was statistically significantly reduced in all but the first condition. However, none of these reductions were clinically significant. Blink rate was observed to be subnormal across all conditions. Therefore, the changes that were seen could be not large enough to show statistical significance.

Reading speed could not be taken as a reliable measure since the variation of reading speed with font size did not come up as an inverted U. The critical print size was statistically significantly larger for the LED lamp than for the CFL lamp when the room lights were kept off. The difference was two logMAR sizes which could also be clinically significant. Under the “Light condition”, however, the difference was only one logMAR size which was not found to be statistically significant. Our LED lamp provided on average 200 lux at the primary task area while the CFL lamp provided 2.5 times that amount. Therefore, this difference in critical print size could be due to the glare produced by the CFL lamp due to its larger light level. On the other hand, at 100% contrast, in the “Light Condition”, (i.e., when the room lights were kept on), the visual acuity change was ½ a line smaller under the CFL lamp than under the LED lamp. This difference in change however is not clinically significant but its statistical significance could be due to the less light level provided by the LED lamp.

Glare was the most commonly complained visual discomfort using both lamps and in both lighting conditions. However, complaint of glare was reported by more number of people when using the CFL Lamp under “Dark Condition” and minimum number of people complained of glare when using LED lamp in the “Light Condition”. In both the dark and light conditions, the LED lamp had the least number of complaints with respect to glare. This could be attributed to the low light level provided by the LED lamp.

Pooled data from the dark and light conditions for both the lamps showed expected difference in the change in visual acuity under the two lamps. However, to our surprise, difference in the achromatic setting was also seen. For these visual parameters, the CFL lamp seemed to have fared well. While it is possible that the effect on visual acuity could be explained by the higher illuminance provided by the CFL lamp, we are not in a position to speculate on the reason behind the difference observed in the achromatic setting. Measurement (or the availability) of the colour rendering index of the light sources used in the two lamps could have thrown some light on this issue.

From the results, we find that there is not much of a difference in the effects produced by the LED based study lamp and the CFL lamp on most visual functions, irrespective of whether the room lights were kept on or off. The performance of the subjects in discrimination of various hues, resolution at various levels of contrast, perception of depth across all four lighting conditions was not much affected in any condition.

In conclusion, the two lamps that we used in our experiment did not produce statistically or clinically significant different effects for the most of the visual parameters we studied. The small number of statistically significantly different affect that we observed could possibly be explained by the vast differences in the illuminances provided by the two lamps. Therefore, we speculate that equalising the illuminances could probably have shown some significant differences. In addition, the near vision tasks were done only for 20 minutes. The task and its duration might not have stressed the visual system to bring out the differences in the effect the two lamps had.

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