

# Effect of Illuminance Uniformity on Paper-Based Reading Performance

*Runjiao Lu<sup>1</sup>, Min-chih Hsieh<sup>2</sup>*

<sup>1</sup> Shanghai World Foreign Language Academy,  
Shanghai, China

<sup>2</sup> University of Shanghai for Science and Technology,  
Shanghai, China

## ABSTRACT

Previously the effect of illuminance and correlated color temperature (CCT) on reading performance had been evaluated. However, the influence among uniformity of illuminance, illuminance, and CCT had not been closely taken into account. Therefore, the aim of current study was to investigate how a particular trait of lighting conditions affected reading performance. The indoor lighting environment was conducted with two uniformity of illuminance and two light conditions. Reading tasks of finding out the incorrect characters and grammatical errors in the manuscript were carried out and the brain activities were recorded by electroencephalogram (EEG). The reading performance was evaluated by signal detection theory (SDT). The results showed that the participants performed better under high illumination uniformity and the lighting condition of 400lx and 3000K. According to the results, this study might inspires the design of indoor lighting in workplace so that working efficiency and quality could be further improved.

**Keywords:** Illuminance; Reading Performance; Signal Detection Theory; EEG ; CCT

## INTRODUCTION

LED is widely used in indoor illumination because of its long working life and low cost. According to the situations where LED is installed, including school, office, restaurants, and shops, various parameters of LED are adjusted to satisfy the emotional and functional influence on human.

Past researchers have clearly studied the effect of different illuminance and correlated color temperature (CCT) on the human performance, especially in simulated office tasks. Questionnaires investigation and electroencephalogram (EEG) based assessment, has proved that attention level and various subjective feelings including comfort, tensity and vividness, were improved under bright environment with high CCT. Meanwhile, the effect of illuminance uniformity has also been take into account in various occasions. The fluorescent light offers preferable uniformity when it's over 0.7, according to subjective rating. The study also discovered that tense tasks requiring concentration favors bright and uniform illuminance.

However, previous studies haven't taken the influence among uniformity of illuminance, illuminance, and CCT into account to evaluate the subjects' performance. Also, the result of questionnaire is seriously affected by the subjective feelings and attitudes. Though xxx utilized EEG to evaluate the attention status, interference from the light of computer screen makes the result less accurate.

Based on the results and limitations of past studies, this study is intending to investigate how illuminance, CCT, and uniformity affect paper-based reading performance. The indoor lighting environment was conducted with two uniformity of illuminance and two light conditions (400 lx, 3000 K and 1000 lx, 5000 K). The reading tasks asked subjects to look for incorrect characters and grammar errors in the manuscripts under each of the four illuminance conditions. Signal Detection Theory (SDT), which is in terms of correct rate, missing rate and false alarm, is used to evaluate the performance of the subjects. Meanwhile, the brain activities were monitored by noninvasive electroencephalogram (EEG). It detected the activities of frontal lobe and occipital lobe that were closely related with information integration, error correction and visual signal processing.

## METHOD

The experiment was conducted in a room of dimensions 4.85(L) × 3.9(W) × 2.5(H) m. The dimension of the desk was 50cm\*150cm. Room temperature was 20-22°C. The independent variables were illuminate uniformity and light combinations, so the indoor lighting environment was conducted with two uniformity of illuminance, 0.101 and 0.058 which is measured by following the PRC National Standards: Measurement Methods for Lighting (GB/T 5700-2008) varied by using two different lamps, and two light conditions (400 lx, 3000 K and 1000 lx, 5000 K).

## EXPERIMENT DESIGN

In the experiment, the independent variables were illuminance uniformity and light combinations. Two values of uniformity of illuminance were 0.101 and 0.058, changed by using two different lamps. The light combinations were 400lx, 3000K and 1000lx, 5000K. To evaluate the level of concentration of the participants, they were asked to find out all the grammar mistakes and character mistakes during the 10-minute reading tasks, while we detected their brain activities by using an EEG equipment. Theory Detection Theory was applied to decide the level of concentration of the participants by analyzing the hit rate, miss rate, and false alarm rate.

The EEG frequency was sampled at 256 Hz and the selected electrodes were FP1, FP2, F3, F4, O1 and O2. The EEG consisted of the following five frequency bands. delta (1-4 Hz), theta (5-7 Hz), alpha (8-13 Hz), beta (14-30 Hz), and gamma (30-45 Hz). Alpha wave rose during concentration, theta wave was related to the slippage of consciousness to drowsiness, and theta wave decreased when a person was in a concentrated state, so theta/alpha can be used as an assessment of the state of concentration, and the ratio of theta/alpha rises when the subject was gradually concentrating. The ratio of these two waves, theta and alpha, was used to analyze the concentration level of the subjects.

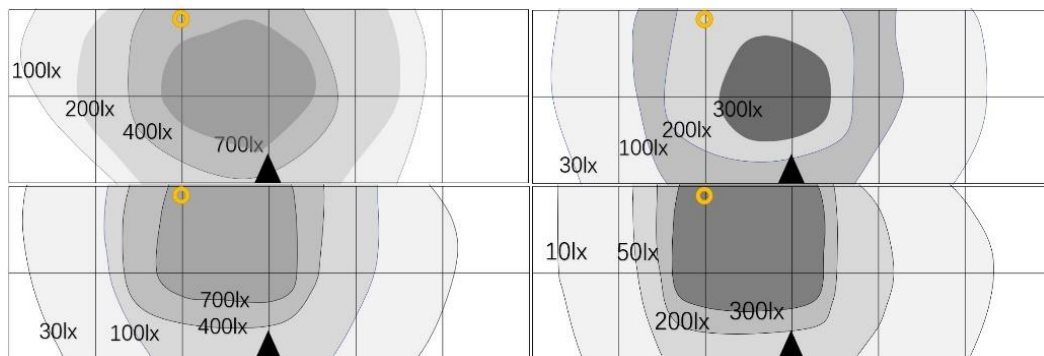


Fig.1: polar diagram of the four illumination condition

A 1000lx,5000k,0.1018    A 400lx, 3000k,0.1020

B 1000lx,5000k,0.0576    B 400lx, 3000k,0.0578

## RESULTS

Fig. 1 showed the comparison between the 1000lx 5000k light emitted from lamp A with that emitted from lamp B. It revealed that the readers under lamp A read 345 more words, which means there was an increase of 14.6% in the average reading words. However, there was a significant difference in the change in correct rate for individuals. Half of the individuals had an increase in correct rate and the other half had a decrease in correct rate. The average change in correct rate was less than 3%.

Fig. 2 showed a comparison of the data from the 1000lx 5000k light emitted from lamp A with the 400lx 3000k light emitted from lamp A, which revealed that the average reading was similar between the two, but there was a significant difference in correctness for a single individual, with half of the individuals experiencing an increase in correctness and half of the individuals experiencing a decrease in correctness, with a 12% increase in the average change in correctness.

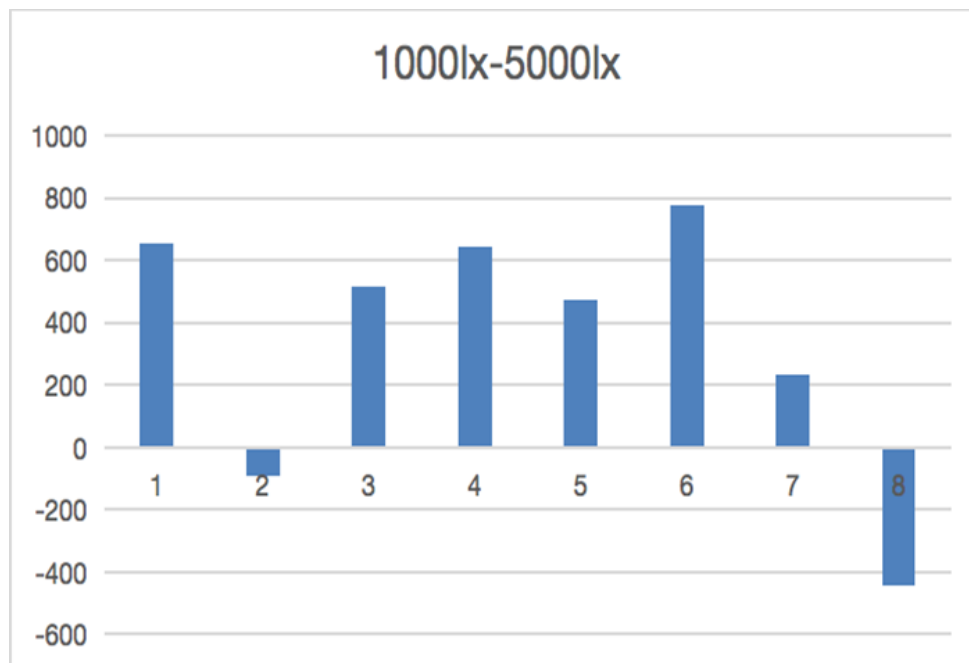


Fig. 1 difference of words read of each person at 1000lx 5000k

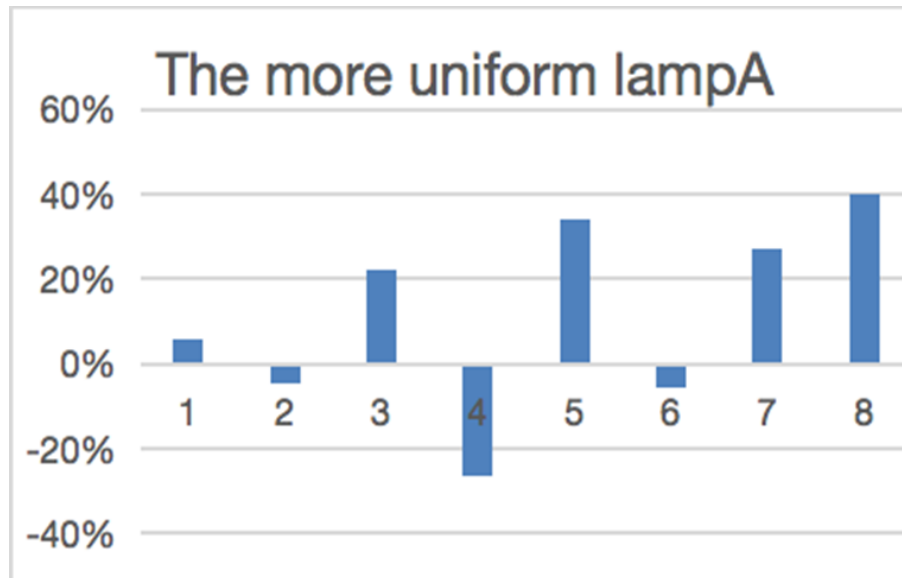


Fig. 2 1000lx 5000k increase in correctness over 400lx 3000k

## CONCLUSIONS

Under the artificial light source with higher CCT and illuminance, lamp with higher illuminance uniformity increased the words read per unit of time. However, there was little improvement in correct rate. It could be concluded that at higher CCT and illumination, high uniformity did not help concentrate on their reading tasks. However, under the same illuminance uniformity, increasing the CCT and illuminance could improve the readers' correctness by raising their concentration level.

Under the artificial light source of low CCT and illuminance, lamp of lower illuminance uniformity improved the correct reading rate compared to the lamp A that was more uniform because it raised the concentration level of participants. However, the lower CCT and illuminance in the concentrated lamp B condition improved the reading speed but reduced the concentration level of the readers.

After comparing the acquired EEG data and analyzing it by using MATLAB plug-in EEGLAB, the absolute power of the five brain waves of six channels for each person was obtained. Comparing the values of theta/alpha of the reader's six channels in the two illuminance uniformity at 1000lx 5000k, it was found that the values of theta/alpha increased by 19.97% under lamp B which has lower illuminance uniformity. Therefore, the EEG performance showed that the less uniform light source at 1000lx 5000k improved the attention of the readers. It also indicated that

the reading environment with less uniform light sources was more effective to affect reading performance by raising concentration, Yet the analysis of reading data didn't coincides with it, because the change in external lighting conditions had a greater effect on EEG while the performance was weak in reading performance.

Considering the 400lx 3000k condition for different illuminance uniformity, the values of theta/alpha for the 6 channels showed that lower illuminance uniformity improved theta/alpha ratio by 6.21%. The performance confirmed the hypothesis that under the lower CCT and illumination conditions, lower illuminance uniformity could improve concentration and therefore reading performance.

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