

Research on the Influence of Indoor Light Environment on Students' Learning Efficiency

-- Based on the Perspective of Human Factors Engineering

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Abstract: As the subject of light perception, people must be more people-oriented in the design of light environment in the classroom. Without proper lighting design, students will not be able to carry out their expected activities efficiently and comfortably. For dealing with different types of learning tasks, whether different light environments have an impact on students' learning behavior and efficiency, and whether students are satisfied with the light conditions in the current learning environment. In view of the above problems, this thesis conducts research from both subjective and objective perspectives, aiming to explore the impact of light environment on students' learning efficiency, as a theoretical basis for optimizing classroom lighting design. In order to verify the influence of light environment on students' efficiency, 32 students were selected for a 12day experiment. From the perspective of human factors engineering, through the combination of physics, medicine and psychology, the effects of light environment on human physiology and psychology were fully considered, and the light intensity produced by different time periods and different lighting methods in the classroom was measured, Human factors engineering method is used to test the learning state of the subjects. SPSS was used to process the experimental data, and the experimental conclusions were obtained. It is concluded that students are more suitable for learning with natural light with uniform brightness distribution within the line of sight and artificial lighting of about 500 lux. The impact of light environment on students was quantitatively studied, and the impact of different indoor light environments on students' efficiency was analyzed. Finally, based on experimental data and human factors engineering theory, reasonable suggestions were put forward for classroom lighting design, which provided a theoretical basis for the study of students' learning efficiency under different indoor light environments.

Keywords: Illumination; Human Factors engineering; Light environment; Learning efficiency.

1. Introduction

The effects of light on the human body can be divided into three parts, firstly light as radiation, exposure to ultraviolet, visible and infrared radiation from light sources can damage the eyes and skin through thermal and photochemical mechanisms, secondly light processed through the visual system, light that allows us to see objects, but uncomfortable lighting conditions can lead to eyestrain, and thirdly light operated through the circadian rhythm system, this point which directly affects human sleep patterns [1]. For students, most learning tasks are done in learning spaces, including classrooms and libraries, where light not only affects their visual health, but also their learning, and the data reported in the literature myopia rates among university students varies, but most of them are not less than 80%, with some research reports showing figures of more than 90% [2]. The data show that the myopia rate among college students is increasing year by year, which is a problem that needs to be solved urgently [3].

Based on the above status quo, the design of light environment in learning places is particularly important. Based on the above situation, the design of the light environment in learning places is particularly important, and a healthy classroom light environment should firstly make full use of natural light and reasonably set up artificial lighting. From previous studies, we can see that the design of indoor light environments gives too much consideration to functional and economic factors, ignoring the impact on human

psychology and physiology, and most of the studies are based on users' subjective perception questionnaires, which lack objectivity and do not take into account the impact of light environments on students' eye health and learning efficiency. The effect of indoor light environment on human body is most intuitively reflected in the changes of human physiology and psychology. Therefore, according to the method of brain load evaluation in human factors engineering, this paper sets up relevant tasks to test students' learning efficiency under different working conditions of the light environment at , and proposes the design of light environment suitable for students' learning by combining with the heart rate variability index, the magnitude of the change of blood pressure, and the subjective perception questionnaire.

1.1. Current Status of Domestic and Overseas Research

Through reading the literature survey, foreign scholars on the light environment research is more comprehensive, in the evaluation illuminance, colour temperature have research, and combined with mathematical models for quantitative research, Chinas classroom space lighting environment research is relatively scarce, evaluation system and centre of gravity design is mainly based on optical performance, less consideration of visual comfort, in the design of the lighting and the environment, the human body comfort is indispensable, not only to ensure eye health, but also to create a healthy and comfortable learning environment for students, which helps to improve learning efficiency. When designing

lighting and environments, human comfort is essential, not only to ensure eye health, but also to create a healthy and comfortable learning environment for students, which helps to improve learning efficiency.

Generally speaking, the research on human factors engineering started earlier in foreign countries, and most of the research focuses on human health and the improvement of labour conditions by using the theory of human factors engineering. Currently, the development of human factors engineering in China is good, and the research direction is mostly used to reduce human errors, reduce the risk of accidents, and improve production efficiency, etc. However, most of the researches are based on the relevant theories in foreign countries for further optimisation or basic researches on the application of models. There are still major gaps in theory, research methodology and application verification. Relevant fields and important functional departments have not yet deeply understood the value and significance of human factors engineering, and have invested less in basic research, and there are still many difficulties in carrying out relevant major engineering applications. In addition, many universities have not offered relevant courses and set up the discipline direction of human factors engineering.

1.2. Methodology and Content of the Study

1.2.1. Research methodology

(1) literature review

This thesis adopts a combination of theoretical and empirical methods, reviewing domestic and international academic papers on the impact of lighting conditions on students' learning behaviour and efficiency, collating and analysing the relevant literature, and refining the cutting-edge ideas and theories of scholars in the field, so as to provide theoretical basis and guiding methods for the thesis research.

(2) Field research method

Through the field research, selecting suitable investigation objects, through the instrument relevant light environment data for field measurement, purposeful, planned, systematic indoor lighting conditions for systematic analysis, in-depth analysis of the existing problems, and summarise.

(3) Questionnaire method

The questionnaire method is a way for researchers to collect reliable information by using controlled measurements to measure the problem under study, and this study used a subjective questionnaire to collect data on the subjective perception of respondents on their learning efficiency under different indoor lighting environments.

(4) Experimental method

The experimental method is a scientific way of being able to confirm correlations between things, the essence of which is to control the variables of the study. This study focuses on comparing the ability of students to perform the tasks specified therein by controlling a variety of environmental variables. In different situations, depending on the needs of the study, different methods and techniques are used to reduce or eliminate the interference of various extraneous factors that may affect science, and the purpose of this study is to identify objects that are in the following states: simplification and clarification--The causal relationship between the visual environment and the learning of pupils' behaviour and abilities can be determined empirically.

1.2.2. Content of the study

Interior lighting design has three basic elements, including people, space and light source. Therefore, the construction

and development of space and environment should be centred on human needs and physiological characteristics - to meet human needs, human psychology and physiology as well as the protection of the visual environment is the primary factor. The creation of a light environment should be based on human needs, and technology should be used to satisfy human needs in the space. Therefore, this thesis simulates different indoor space light environment models based on the perspective of human factors engineering in one of the classrooms of Southwest Petroleum University, and through the comparison and analysis of the simulation results of the different models, the optimal arrangement of lamps and desks is obtained.

1.3. Points of Innovation

(1) Adoption of cross-disciplinary research methods. This paper applies theoretical knowledge from optics and medicine and other related fields to explore and analyse the interaction between the light environment and students' learning behaviour and efficiency in a multi-dimensional way, constructs a theoretical framework for the empirical study, and explores the influence of the light environment in the classroom on the students' learning behaviour and efficiency in terms of the subjective perception questionnaire, the learning task test, and the measurement of physiological parameters, etc., which not only provides theoretical evidence of the influence of the light environment on student learning, but also provides a development path for the design strategy of the light environment in the classroom to draw on. This study not only provides a theoretical basis for the impact of light environment on students' learning, but also provides a development for the design strategy of light environment in classrooms.

(2) Introducing the theory of human factors engineering, applying the theory of human factors engineering to the design of the classroom light environment, integrating the human-centred idea into the experimental design and light environment design strategy, and analysing the effect of the classroom light environment from the perspective of suitable for students' learning.

2. Experimental Design of The Study on The Effect of Indoor Light Environment on Students' Learning Efficiency

2.1. Selection of Subjects

The selection of the number of subjects is based on the minimum sample rule of mathematical statistics, i.e., the sample size $n \geq k+1$, where k is the number of explanatory variables, and when the experimental sample is large enough ($n > 30$), the distribution of the mean is asymptotically normal [4]. Since this study mainly focuses on university students, the subjects selected in this paper are 32 undergraduate students of Hebei University of Engineering, and in order to balance the variable of gender, 16 males and 16 females, aged between 19-23 years old, were selected to participate in the experiment voluntarily. Each was in a healthy state, had sufficient reading and cognitive ability, had normal vision and above, and had no less than 5 diopters of visual acuity corrected by tools, with a visual acuity correction of less than 400 diopters. Because vision can affect the results of the experiment, each participant in the experiment was tested for colour blindness in Ishihara and underwent a visual acuity

survey prior to the experiment. Before taking the test, participants should ensure that they have enough sleep, remain emotionally stable, do not take any psychotropic substances during the test, and do not consume any such as alcohol, tea polyphenols, caffeine or other stimulants within 12 hours before the test.

2.2. Introduction to the Experimental Apparatus

The instrument is divided into two parts: the first part is used to measure whether the indoor environment meets the experimental criteria: light intensity; the second part is used to measure the physiological parameters of the subjects during the experiment: heart rate and blood pressure.

(1) Measurement of environmental parameters

The air-conditioning system controls the temperature and humidity in the room and displays them on an electronic screen, so all that is needed is to measure the illuminance in room. For the actual measurement, it is preferable to choose instruments that are convenient, compact and easy to operate. The measuring range and usage requirements of the instrument meet the experimental conditions, and its maintainability and cost are small. Therefore, the digital photoelectric illuminance meter is chosen for this experiment. The illuminance meter used in the experiment is the TA632A high-precision digital photometer, which is specialised in measuring illuminance. The illuminance meter can be customised with light source coefficients, it is small in size, light in weight, simple in operation, reliable in performance, has a range of 200,000 lux, a resolution of 0.1 lux and can record 50 sets of data. The recording interval can be set from 2 seconds to 24 hours. It is often used in schools, offices, homes and other illuminance measurements.

(2) Measurement of human physiological parameters

In medical diagnosis, the commonly used sphygmomanometers right wrist sphygmomanometer, mercury sphygmomanometer and arm sphygmomanometer. Because of the convenience of carrying and measurement in the experiment, so the selection of wrist sphygmomanometer wrist electronic sphygmomanometer measurement is the wrist artery "pulse pressure value", so the measurement value will be deviated, but the wrist electronic sphygmomanometer is easy to carry, compact shape. The model of the wrist sphygmomanometer used in this experiment is the fully automatic pressurised vibration measurement method, with a pressure measurement range of 0-330 mmHg, a blood pressure measurement range of 30-270 mmHg, a pulse measurement range of 40-200 beats per minute with an accuracy of ± 3 mmaHg (± 0.4 kPa) or less, and a record of 60 sets of values.

2.3. Introduction to Measurement Methods

In the illuminance measurement of the specified area will be divided into the average measurement area of the same size rectangle, generally set the shape as a square, should be in the centre of the rectangular grid to measure the illuminance, the layout method is applicable to the horizontal illuminance, vertical illuminance, or vertical illuminance measurements in the direction of the camera [5].

According to this experiment, the experimental desktop was divided into a 100 mm \times 100 mm grid, and the height of 0.75 m measurement surface was selected. The illuminance data were processed by averaging two measurements at each measurement point and calculating the arithmetic mean of the

illuminance at all measurement points, which was taken as the average illuminance of the 0.75 m horizontal plane in this lighting environment.

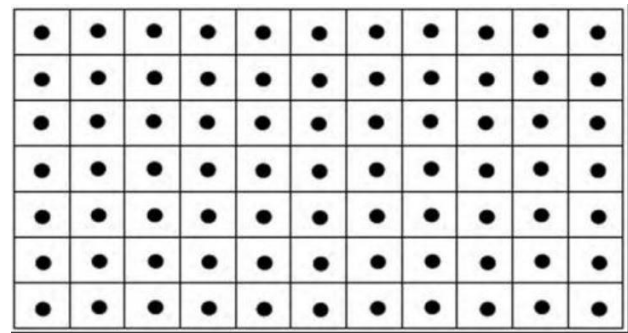


Figure 1. Measuring point method diagram

2.4. Experimental Flow

For each experiment, the duration of the test did not exceed 50 minutes, except for the adaptation to a time period of no more than 80 minutes, and even within each time period, the subjects were able to fully complete the test, which required fluorescent light working conditions and a physical set-up of the laboratory approximately one hour prior to the scheduled date. Prior to the start of the experiment, the day before the experiment, in order to familiarise the subjects with the procedure and to pay attention to the details, a briefing was given to the subjects, including the duration of the experiment, the attention to the questionnaire, the parameter measurement tools, the use of the experimental parameters, etc. Since the subjects could not measure the visual environment with the instrument, they were asked to fill in the questionnaire based on their subjective perception in order to obtain reasonable experimental data.

The experiment was divided into four stages: pre-test preparation, measurement of physiological parameters, test of learning efficiency, and completion of a subjective questionnaire. Prior to the start of the experiment, subjects were informed that the duration of the experiment would be approximately 1.5 hours, that they would not be allowed to leave the experimental environment during the experiment, that they would not be allowed to leave the experimental environment before the start of the experiment, that they would be given a full explanation of the experimental procedure, that they would be given a description of how to fill out the forms required in the experiment, and that they would be given a chance to fill in the forms once prior to the experiment, to ensure that they understood the rules of filling out each type of scale. Each subject was required to enter 10 types of experimental environments. 10 lighting environments were divided into 4 groups, each group was set up according to the experimental conditions, and the test was conducted within 30 minutes after the preparation, and the physiological parameters of each subject were measured before the test started. the end of the test, each participant filled out a subjective evaluation questionnaire based on his/her true feelings about the current working conditions, which took about 3-5 minutes. After completing the questionnaire, blood pressure and heart rate were measured using a wrist-mounted sphygmomanometer, which took about 3 minutes to complete. During the experiment, the ambient temperature, illumination and other physical parameters were measured several times to ensure the accuracy of the experimental conditions.

3. Analysis of the Impact of Indoor Lighting Environment on Students' Learning Efficiency

3.1. Methods of Analysing Data

Reliability is the degree of consistency of the results obtained from repeated measurements of the same object using the same method. In order to ensure the validity of experimentally repeated questionnaires, the reliability of the questionnaire must be analysed, and Cronbach's alpha reliability coefficient is the most commonly used reliability coefficient [6], and the alpha reliability coefficient method is adopted in this paper.

3.2. Data Collation Methods

(1) Learning efficiency evaluation methods

In this experiment, there are four types of items in the learning task test, which can test the subjects' four aspects: concentration, perception, memory and logical reasoning. In order to facilitate the analysis of the subjects' completion of each test, we introduced the indicators of correctness AC and reaction time RT, the higher the correctness rate and the shorter the reaction time, the better the test is [7]. However, if AC and RT are analysed separately, it will not only make the analysis more difficult but also lead to inaccurate results, therefore, a composite indicator LP is introduced [8], which is a composite indicator used to measure the learning efficiency.

$$LP = \left[AC^{0.5} \times \left(\frac{1}{RT} \right)^{0.5} \right]^2$$

(2) Data collation

In this paper, the basic experimental data were counted and entered into excel tables for preliminary analysis, subjective experimental questionnaire data, physiological parameter measurements were collated and entered to calculate the average value of each item, and the function calculation function in excel was used to calculate the comprehensive performance value of each learning task.

(3) Normality test

The experimental data in this paper were statistically analysed using the statistical software SPSS23.0. Generally used K-S test or S-W test to verify whether the data obey normal distribution, the main difference between the two is that the K-S test is generally used in the case of a large sample size and the continuous occurrence of data, while the S-W test is generally used in the case of a smaller sample size, according to the experimental data collected in this paper, the K-S test is adopted. According to the experimental data collected in this paper, the K-S test is adopted, in which the K value represents the peak value of the data, and the S value reflects the symmetry of the data. The K-S test is applied to the data of this paper by SPSS, and the data are normally distributed.

(4) Significance test

In this paper, one-way ANOVA and Pearson's product moment correlation coefficient are used for analysis. Pearson Correlation Coefficient method is a statistical method, the P-value was firstly formally introduced by Karl Pearson's Pearson in the chi-square test, which can measure the correlation of the variables in a quantitative way, and the most commonly used one is Pearson's product moment correlation coefficient [9]. The smaller the p-value, the more reason there is to believe that there is a difference between the

comparisons. For example, a p-value of less than 0.05 means that the results indicate a difference of less than 5 per cent due to a difference in probability, or that there is less than a 5 per cent chance that someone else will repeat the same study under the same circumstances and come to the opposite conclusion. ANOVA can also be analysed using Cohen's f for effect sizes, which indicates that the thresholds for distinguishing between small, medium and large effect sizes are: 0.10, 0.25 and 0.40 respectively [10].

3.3. Combined Effect of Light Environment on Test Results

The results of different light environments on students' concentration, perception, memory, and logical reasoning for each learning task have been listed above, but in the daily learning process, it is necessary for a variety of abilities to work together in order to effectively improve the learning efficiency. Therefore, in order to consider the influence of the light environment on students' learning efficiency, the results of each test were analysed by Pearson correlation coefficient, and the influence of the light environment on learning efficiency of each type was analysed. Correlation analyses were conducted to study the effects of mental arithmetic, Amphenomov, short-term memory, and graphical reasoning under 10 conditions, and the Pearson correlation coefficients were used to express the strength of the correlations. It can be seen from the analysis that the light environment has a significant effect on the students' completion of mental arithmetic test, and the correlation coefficient is -0.803, and the correlation coefficient is less than 0, which means that there is an inverse relationship between the completion of mental arithmetic test and the light environment. Different working conditions also showed a significant effect on the Anfimov table test, the correlation coefficient value was -0.929, and the correlation coefficient value was less than 0, which means that there is a negative relationship between the Anfimov test and the light environment. The correlation coefficient values were -0.737 and the correlation coefficient values were less than 0, which means that there is a negative correlation between short-term memory and light environment. Due to the difficulty of the graphical reasoning questions, the influence of different working conditions on the graphical reasoning test results is small, resulting in a correlation coefficient value of -0.495, which is close to 0, and the p-value is greater than 0.05, which means that there is no significant correlation between graphical reasoning and the light environment.

From the different shades of colours in the Pearson's correlation visualisation, it can be seen that the light environment has a comparable effect on students' perceptual ability and short-term memory, with the most significant effect on perceptual ability and an insignificant effect on logical reasoning ability. For students' learning, different types of learning tasks require different indicators, which can be arranged in appropriate time periods according to the specific types of learning tasks, for example, English courses need to mobilise students' memory, which can be arranged in the first class in the morning, which is more conducive to the learning of such courses; architecture students need to mobilise perception, which requires a higher demand on the light environment, and requires more rigorous arrangement of the course time. The architecture students need to mobilise their perceptions and have higher demands on the light environment, so it is more necessary to arrange the course

time rigorously.

3.4. Combined Effect of Physiological Parameters on Learning Efficiency

There is no significant correlation heart rate and blood pressure on the Anfimov table and graphical reasoning ($p>0.05$), while heart rate and blood pressure have the greatest impact on the mental arithmetic test. It can be seen that the change of illumination affects the change of physiological parameters in a short period of time, the higher the illumination, the higher the increase of heart rate and blood pressure, and improvement of students' performance in a short period of time, but the effect is not significant.

3.5. Analysis and Discussion of Results

The subjective questionnaire results show that the students are more satisfied with the working conditions ①, working conditions ③, comfort also higher, eye fatigue is lower, corresponding to the illumination value under the natural light source: 900lux and the illumination value under the artificial light source of 587lux. for the natural light, in the morning, the natural light in the change of natural light in the continuous, the change of brightness is not obvious, that is, the transition of light is natural, the human eye can not detect the subtle difference, so the eye irritation is not too high or too low for the artificial lighting is not suitable for students to study. The human eye cannot notice the subtle difference, so it is not very irritating to the eyes, and the sunlight is directed into the window to make the brightness uniformly distributed within the range of vision. artificial lighting, too high or too low is not suitable for students' study, and artificial lighting around 500lux is more popular among students.

The results of the learning efficiency test show that the learning efficiency is low in working conditions 7 and 8, and the overall performance is significantly higher in working conditions 1 and 3. During the time when the sunlight is the strongest, no matter facing the natural light directly or facing the sunlight sideways, too strong illumination will cause eye discomfort, and too high illumination will increase the burden on the visual nerve and distract the attention, thus lowering the learning efficiency. Too much light increases the burden on the visual nerve and distracts attention, thus reducing learning efficiency. Too little light causes visual fatigue, which affects learning efficiency and may even lead to vision loss. Appropriate sunlight and artificial light are both conducive to learning. From the comprehensive analysis, we can see that the light environment has a significant impact on students' concentration, perception and memory, especially on perception, but not on logical reasoning. Therefore, when arranging students to study different types of courses, it is necessary to consider their effects, for example, courses with a greater demand for perception can be arranged in the time period when natural light conditions are better, and desks and other facilities can be placed by the window; courses with a greater demand for memory can be arranged in the time period close to the morning as much as possible.

Physiological measurements showed a positive correlation between heart rate and blood pressure and the magnitude of illumination. When the illumination level increases, the ambient temperature rises, the body's core temperature rises, the body temperature rises causing the heart rate to increase, and the body temperature rises causing the blood vessels to dilate and the blood pressure to decrease. In high illuminance environments, the environment increases the level of arousal

of the human brain, resulting in an increase in the value of learning performance. However, excessive illuminance causes the body to its mental investment and fatigue, and the changes in heart rate and blood pressure indicate that the increased sympathetic activity causes an increase in the feeling of discomfort, which in turn affects the efficiency of the learning process.

The eye is initially in the natural light evolution and growth, after hundreds of years of evolution, naturally with the highest degree of adaptation to natural light, early morning sunlight is the more soft and comfortable light of the day, but also to make the eyes feel the most comfortable light, natural light is a mixture of many different wavelengths of colours, which the blue light, which is reflected by irradiating objects before entering our eyes, the most beneficial to the health of the eyes, so as far as possible in the classroom lighting to make the students learning environment in the uniform natural light irradiation. Therefore, in the classroom lighting as much as possible to make the student learning environment in the uniform natural light irradiation, in the bad weather, poor light in the period of time to choose the appropriate illumination lamps and lanterns, to minimise the negative impact of light on student learning.

4. Conclusion

For university students, most of their time is spent in the classroom, and the indoor light environment has a great impact on their psychological and physiological health as well as their learning efficiency. In previous studies, most of the research on the light environment focuses on energy saving and environmental protection, and there is a lack of quantitative indicators for the study of light on the human body. Based on the perspective of human factors engineering, this paper firstly analyses the theoretical basis of the light environment in the classroom and the indexes of learning efficiency, and through experiments, it explores the effects of different light environments on the comprehensive performance of students' learning, and explores the light environment that is the most suitable for students' learning. The findings of the thesis are as follows:

(1) The subjective feeling questionnaire and learning efficiency test items are added in this paper, and the effects of different natural light conditions on the overall performance of students' learning tasks are investigated through experiments, and the illumination level has a significant effect on the learning efficiency of the students. The effects of natural light on the students in different time periods and the effects of different natural light in the same time period are taken into consideration. It was shown that as the illumination level increases, it is not the case that a higher light level has a greater effect on the improvement of the students' learning efficiency, but that when the light level reaches a value, it sometimes has a side effect. We also found out the light environment that corresponds to the best completion situation, and the students' learning efficiency was higher in the 8:30 am time slot facing natural light and the environment with artificial lighting.

(2) Through experiments to explore the effects of different natural light conditions on students' physiological indicators, the impact of the light environment on students health is visualised in the form of figures, the results of the experiment show that illuminance value does not have a significant effect on students heart rate and blood pressure, but the heart rate and blood pressure increase slightly with the increase in

illuminance value, and the heart rate of boys is generally lower than that of girls, but the blood pressure value is generally higher than that of girls. The heart rate of boys is generally lower than that of girls, but the blood pressure is generally higher than that of girls.

There are other experimental variables that were not taken into account in this paper, and there is some work that deserves to be developed in a follow-up:

(1) There are other relevant experimental variables that are not represented in this experiment, whether there is an effect of colour temperature as well as spectral changes under different light conditions, and the effect of room temperature remains to be examined.

(2) In this paper, the experimental research group is college students, but not on behalf of all groups need to study, there are many other groups in other environments learning factors worth exploring, in the future research needs to be carried out different age levels and different occupations to study or read books in the light of the environment, in addition to the subject of the relevant theoretical results have not been put into practical action.

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