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Retraction

Retracted: The Evaluation of Visual Clarity and Comfort of Light Environment in Multimedia Classroom

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Dong, M. Xi, and M. Hu, "The Evaluation of Visual Clarity and Comfort of Light Environment in Multimedia Classroom," *Journal of Robotics*, vol. 2022, Article ID 4917352, 12 pages, 2022.

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Research Article

The Evaluation of Visual Clarity and Comfort of Light Environment in Multimedia Classroom

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In order to clarify the quantitative relationship between students' visual clarity, comfort, and environmental brightness in the light environment of multimedia classrooms in colleges and universities and obtain the threshold and influence trends of brightness, visual clarity, and visual comfort in the light environment of the multimedia classroom, this paper proposes the research on the relevant influence parameters of the light environment of the multimedia classroom. Based on the analysis of the current situation of multimedia use in China, this paper proposes taking brightness as the main parameter of indoor light environment evaluation to carry out students' subjective evaluation experiments. The brightness range that can reflect the visual clarity and visual comfort of the experimenter is extracted by using multimedia combined with screen projection and HDRI technology. Finally, by analyzing the experimental data, combined with the operational definition of the psychophysical threshold, the functional relationship between visual clarity, comfort, and brightness in the light environment of a multimedia classroom is obtained through regression analysis and the threshold and extreme point data are calculated. The experimental results show that when the brightness range is $370.83\ cd/m^2 \le X \le 558.47\ cd/m^2$, it has better visual clarity and visual comfort. When the brightness contrast is close to 10 : 1, the visual clarity is the highest; when the brightness contrast is close to 5 : 1, the visual comfort is the highest and decreases on both sides with the change in its value. *Conclusion*. The results of this experimental study can provide a basis for formulating and revising relevant laws and regulations in the future and provide a reference for the light environment design of multimedia classrooms in China.

1. Introduction

The light environment refers to the physiological and psychological environment related to spatial functions and shapes established indoors by the changes in light (natural lighting and artificial lighting) and color (hue, color temperature, expressiveness, and color distribution) [1]. A light environment is mainly divided into a natural light environment and an artificial light environment. A natural light environment is natural lighting, that is, the indoor use of natural light. An artificial light environment is artificial lighting, which uses light-emitting lamps to supplement the insufficient lighting in the building space during the daytime due to time, weather, and other reasons. It is an artificial measure taken to meet the needs of study, life, and work. It can be flexibly adjusted according to people's needs to achieve the ideal lighting effect.

Different building types have different requirements for the light environment because different space functions have different requirements for light. In the buildings shown in the "Building Lighting Design Standard GB 50034–2013," the required illumination values are also different according to the type of activity [2]. The design of architectural lighting environments is no longer relying solely on the norms and standards of lighting and lighting, but developing toward a humanized design concept. The evaluation and research of architectural lighting environments are also gradually improving. According to the different evaluation indicators, the evaluation of indoor light environments in buildings is mainly divided into two types. One is partial quantitative evaluation research, which is a comprehensive evaluation based on objective indicators such as illumination and brightness. It needs to measure the physical parameters such as illumination of the light environment in the building space and then refer to the relevant standards to evaluate the advantages and disadvantages of the light environment. The other is qualitative research, which directly uses subjective evaluation indicators such as comfort for a comprehensive evaluation, which requires a large number of subjects to participate in the experiment [3]. Because there are relevant standards and specifications for objective indicators, they can be measured and evaluated by relevant instruments. However, the selection of subjective indicators involves knowledge in many fields, such as human psychology and ethology, and the evaluation process is also complex.

2. Literature Review

Zheng and Crowcroft put forward the indoor light environment comfort curve and believed that for any given environmental color temperature (for other light sources that imitate the light color of solid discharge light sources, we use the relevant color temperature), there is a comfortable illumination range; values lower than this range will make people feel dark and cold, and values higher than this range will make people feel unnatural [4]. Gerla and Tzu-Chieh Tsai reviewed the research results on the visual comfort of the indoor light environment in recent ten years, made a multidimensional evaluation and description of various indicators describing the attributes of the indoor light environment, and put forward optimization suggestions when using these indicators, providing a design basis for relevant practitioners in the construction industry [5]. Zhao et al., by investigating the illumination of the working face under the indoor light environment and the satisfaction of users with the light environment, showed that the approximate relationship between the satisfaction of the indoor light environment and the illumination of the working face is obtained using the method quadratic regression fitting, and it is pointed out that when the illumination of the working face is 100–2100 LX, people are satisfied with the indoor light environment, while when the illumination of the working face is 1000–1200 LX, the satisfaction of the light environment is the highest [6]. Wang et al. set the working surface illumination of 200–900 LX in the artificial lighting experimental room to determine the working surface illumination difference between the best visual efficacy and the best visual comfort of indoor space users under working conditions. The results show that the subjects' visual efficacy is the best under the illumination of more than 900 LX, and the illumination between 400 and 500 LX makes the subjects feel the most comfortable. It is suggested that the visual comfort factor should be properly considered in the lighting environment in pursuit of efficient work and mental stimulation [7]. Kumar et al. studied the visual comfort of subjects in screen reading and paper reading under different combinations of illumination and color temperature in a small office space through a subjective evaluation experiment. The experiment set 500 LX and 750 LX illuminance and 3000 K, 4000 K, and 6500 K ambient color temperature combination conditions for these two visual tasks [8]. The experimental results show that the color temperature of the light source is very important for the visual comfort and psychological feelings of subjects. The combination of low color temperature and low illumination and high color temperature and high illumination is more in line with the psychological preferences of users. The research results of Puguan et al. show that the illumination below 300 LX cannot meet the user's visual comfort needs, the illumination above 500 LX is meaningless for improving visual comfort, and the influence of the change in correlated color temperature (CCT) on the brightness of the light environment and the degree of psychological pleasure can be ignored [9].

Scholars at home and abroad mainly explore the evaluation of visual suitability from the two aspects of visual clarity and visual comfort. Although there are many research directions and conclusions about the classroom light environment at home and abroad, there are still deficiencies: there are few studies on the multimedia classroom light environment with the brightness received by the evaluation subject as the main evaluation parameter. And there is a lack of quantitative research on the subjective evaluation of students' visual clarity and visual comfort combined with objective experimental data.

Based on the subjective feelings of college students on the light environment of a multimedia classroom, this paper uses high dynamic image (HDRI) technology and considers brightness as the main parameter to evaluate the quality of a classroom light environment. The influence of the light environment in a multimedia classroom on students' visual clarity and visual comfort is evaluated subjectively and experimental data are collected, and then quantitative analysis and research are carried out. Combined with the operational definition of psychophysical threshold, the functional relationship between visual clarity, comfort, and brightness in the light environment of a multimedia classroom is obtained through regression analysis, and the threshold and extreme point data are calculated. Finally, the threshold and influence trend that can be used to determine the brightness range, visual clarity, and visual comfort of the multimedia classroom light environment are obtained. Discussing the relationship between the visual clarity, comfort, and environmental brightness of a multimedia classroom can provide a reference for the design of a multimedia classroom light environment and the formulation of relevant standards in the future.

3. Research Methods

3.1. Relevant Methods

3.1.1. Evaluation Method. At present, the measurement of subjects' visual clarity and visual fatigue at home and abroad basically means to measure the indicators related to visual clarity and visual fatigue, so as to indirectly quantify the indicators related to visual clarity. According to the experimental content of this study and the characteristics of the tested personnel, the following two methods are designed:

(1) Subjective evaluation and feedback evaluation of visual clarity and visual comfort are done, using a questionnaire designed on the basis of the semantic difference scale under the Likert scale. Using appropriate visual subjective evaluation methods, we describe fatigue characteristics such as sleepiness, and eye discomfort. According to different evaluation methods, a survey screening questionnaire, a subjective evaluation questionnaire, and a return visit questionnaire were designed [10].

(2) Measurement of visual ergonomics is done. According to the number of jobs completed and the error rate, the work materials of the visual fatigue state are designed, and a variety of work materials such as the digital recognition table and graphic recognition (Landao ring) are selected for experiments.

3.1.2. Visual Recognition Object. This experimental test adopts the light environment of the classroom under a variety of light climate conditions, from dark night to overcast day, and then to the brightness range of the indoor light environment when there is no cloud on a sunny day, so it can reflect the corresponding experimental results from a large range [11]. Through the natural lighting and the shielding of the classroom shading curtains, and combined with the lighting lamps on or off, the indoor light environment can be adjusted and the screen brightness of the projector will not be adjusted.

We use thevisual acuity test table, text, pictures with rich colors and details, and computer courseware for making software PowerPoint to construct text files with multiple colors and numbers of different sizes, which is convenient for the subjects to judge the visual clarity under each situation and can also avoid the influence of color equality factors on the experimental results. The Latin square design and the circulation method are used to offset the result errors caused by the participation order, projection, and playback order of students participating in the evaluation experiment and their own factors.

3.2. Experimental Design

3.2.1. Selection of Experimental Parameters. In the past, the analysis and research of the light environment of multimedia classrooms by experts and scholars mostly used the illumination of teaching working surfaces such as desktops and blackboards, and even the surface illumination of eye positions as the physical parameters to measure the light environment of multimedia classrooms, and rarely used brightness as the physical parameter to measure the light environment. Since brightness itself is people's feeling of light intensity, it is a quantity that can more directly reflect people's subjective feelings [12]. The relevant national specifications only make relevant provisions on the illumination in the indoor light environment of the building but do not put forward guiding suggestions on the indoor light environment of the classroom with the change in environmental brightness and the use of multimedia facilities. In the past, brightness information was usually not used as the main reference parameter in research. The main reason is that the collection and extraction of brightness information is a relatively difficult process compared with other physical parameters. However, with the progress of measurement technology and scientific methods, the direct extraction of brightness parameters can reflect the light environment of indoor places in buildings. Therefore, this experiment takes the brightness parameter as the reference basis and takes the brightness information of relevant points, such as the highest brightness value, the lowest brightness value, the average brightness of the place, and the brightness of relevant points as the main reference parameters.

3.2.2. Extraction Method of Brightness Parameters. In this paper, the high dynamic range image (HDRI) technology with floating-point value storage is used as the method for extracting brightness parameters in experiments. In this experiment, the Canon 5D Mark II, a full-frame CMOS photosensitive element digital SLR, combined with a 50 mm standard lens, is used to extract the brightness parameter information within the normal field of view. First, time-sharing and multiple exposure shooting are carried out on the test target in the same light environment scene to obtain low dynamic digital images with different exposures [13]. Then, using professional image synthesis software Photomatix 5.1 and Photoshop CS6, low dynamic range images with different exposure levels are synthesized into high dynamic range images. After synthesizing the high dynamic range image, the brightness and brightness contrast information in the image are accurately extracted from the picture through the software HDR viewer v1.4, independently developed by Tianjin University.

3.2.3. Selection of Experimental Environment and Personnel. The preliminary investigation and data collection of this experimental research show that the typical building plane selection of multimedia classrooms is mostly rectangular, using curtain projection multimedia equipment, one-way side window lighting, or the other side of high side window lighting [14]. Therefore, the "architectural optics laboratory" classroom of a university with the above typical characteristics and the facilities that can actively control natural and artificial lighting to adjust the light environment is selected as the experimental site for the experimental simulation. Thirty-one people aged between 21 and 28 were randomly selected from the University. Half of the students were male, and half were female. Factors that seriously affect vision and judgment, such as color blindness and color weakness, were excluded to ensure that each subject participating in the test had normal color and vision [15].

The selection of test points is based on the lighting measurement method (GB/t5700-2008), the actual use space of the classroom, the evaluation method required by the visual recognition materials and the international visual acuity evaluation table, and the actual use position of the seats in the multimedia classroom. At the same time, combined with the size and position relationship of the projection screen, three groups of nine different test points with a horizontal distance of 3 m, 5 m, and 7 m from the projection screen are selected and the vertical height of the test points from the ground is 1.2 m (the specified sitting height in the lighting measurement method).

3.3. Research Process

3.3.1. Preevaluation Experiment. Through the preexperiment, problems are found, specific experimental measures are adjusted, the experimental scheme is improved, and the final experimental process is determined through a small batch of preevaluation experiments. Each group of experiments is set to be carried out at the specified time and in the experimental scene. The weather conditions are all cloudy and sunny, and each experimental link in the preexperiment is done accordingly [16]. Three time periods, 8 : 00–12 : 00, 13 : 30–18 : 30, and 19 : 00–21 : 00, during which students frequently use multimedia classrooms, were selected for multitime period experiments. The preevaluation experiment is a small sample experiment. Considering the different experimental content settings of this preexperiment, the experiment was divided into three parts according to the change in experimental duration and experimental content in each part. According to the requirements of the Latin square design, six people were selected for the experiment. Visual tests were conducted on each participant to ensure that each participant in the test had normal vision.

3.3.2. Large Batch Evaluation Experiment. Through the preevaluation experiment, the more extreme influence parameter values are removed, the remaining parameter quantities are found to be significantly different, the parameter range becomes smaller, and the brightness difference spacing is appropriate. Then, the screening results of the preexperiment parameter data are screened and optimized again, and the experiment is carried out on this basis [17]. Then, through the subjective evaluation experiment of a large sample size, a large number of experimental data are obtained, and the change rules and thresholds of visual clarity, visual comfort, and brightness contrast are obtained through calculation.

According to the subjective evaluation of large batches of experiments, a total of 1116 experimental data were obtained: 558 visual evaluation homework materials and 1116 evaluation questionnaires, feedback questionnaires, and interview questionnaires. We arrange the average scores of visual clarity and visual comfort according to the scoring method of preexperiment. The statistical results of the average scores under different experimental parameters are shown in Table 1.

In this experiment, the data obtained from the preexperiment and the large batch evaluation experiment are analyzed as follows.

(1) Reliability Analysis. In this paper, the internal reliability analysis of the Cronbach coefficient is used for the reliability analysis. Through the basic description statistics and calculation of each evaluation item by using SPSS computer software, the reliability coefficients of visual comfort and visual clarity of the preevaluation experiment were 0.828 and 0.882, indicating good internal consistency. In the large batch of subjective evaluation experiments, the reliability coefficients were 0.805, 0.811, 0.832, 0.795, 0.821, and 0.756, respectively, which are close to 0.8 and above, indicating high consistency.

(2) Correlation Analysis. According to the SPSS analysis results of this preexperiment correlation analysis, with the change in brightness in the field of vision, the mean Pearson correlation of the average score of visual clarity and visual comfort changes regularly and the absolute values are above 0.8. When the brightness values of the two are at the highest points of the two, 500 cd/m^2 and 400 cd/m^2, there is a strong positive correlation, the correlation being 0.826 and 0.912, respectively, and there is a strong negative correlation after the highest point and the absolute values of the correlation are 0.964 and 0.985, respectively.

The correlation data of a large number of subjective evaluation experiments are obtained. Among them, we have the following: ① visual acuity: when the brightness value is 500 cd/m^2, it reaches the highest point of the evaluation value, and the values before and after it decrease. The analysis results show a significant correlation, and the absolute value of the correlation value is 0.92; ② visual comfort: when the brightness value is 400 cd/m^2, it reaches the highest point of the evaluation value, and the values before and after it decrease. The analysis results are significantly correlated, and the absolute value of the correlation value is 0.865.

At the same time, the Pearson correlation between the change in brightness contrast and the average score of visual clarity and visual comfort also changes regularly and the absolute values are above 0.7. When the brightness contrast is close to 10 : 1, the visual sharpness is the highest and the visual sharpness decreases on both sides with the change in contrast value; when the brightness contrast is close to 5 : 1, the visual comfort is the highest and the same visual comfort decreases with the values on both sides.

4. Result Analysis

According to the setting of the subjective evaluation experimental questionnaire, we take the visual comfort evaluation scale as an example (the visual clarity evaluation scale is also the same). On the subjective evaluation scale, the representative “very uncomfortable” is 1 point, the representative “less comfortable” is 2 points, the representative “general” is 3 points, the representative “more comfortable” is 4 points, and the representative “very comfortable” is 5 points. Also, we give 1 point for “very unclear,” 2 points for “less clear,” 3 points for “average,” 4 points for “relatively clear,” and 5 points for “very clear.”

The threshold value calculated is the threshold value of visual clarity and visual comfort in the light environment of

Table 1: Statistics of average scores of visual acuity and visual comfort in large batches of subjective experiments.

	300 cd/m^2	400 cd/m^2	500 cd/m^2	600 cd/m^2	700 cd/m^2	800 cd/m^2
Visual clarity	2.55	3.78	4.39	3.20	2.23	1.85
Visual comfort	3.53	4.55	4.38	3.05	2.53	2.24

Table 2: Statistical frequency percentage of visual acuity data.

Scoring frequency/percentage		Brightness parameters					
		300 cd/m^2	400 cd/m^2	500 cd/m^2	600 cd/m^2	700 cd/m^2	800 cd/m^2
Frequency	1	1	0	0	0	2	15
	2	44	3	0	21	69	77
	3	44	26	5	37	19	1
	4	4	52	46	30	3	0
	5	0	12	42	5	0	0
Percentage of score	1 (%)	1.08	0	0	0	2.15	16.12
	2 (%)	47.31	3.22	0	22.58	74.19	82.8
	3 (%)	47.31	27.96	5.38	39.78	20.43	1.08
	4 (%)	4.3	55.91	49.46	32.26	3.23	0
	5 (%)	0	12.91	45.16	5.38	0	0
≥4 percentage		4.3	68.82	94.62	37.64	3.23	0
≤2 percentage		48.39	3.22	0	22.58	76.34	98.92

Table 3: Statistical table of visual comfort data frequency percentage.

Scoring frequency/percentage		Brightness parameters					
		300 cd/m^2	400 cd/m^2	500 cd/m^2	600 cd/m^2	700 cd/m^2	800 cd/m^2
Frequency	1	0	0	0	2	8	8
	2	1	3	7	19	32	61
	3	42	2	5	50	40	22
	4	48	37	40	19	13	2
	5	2	51	41	3	0	0
Percentage of score	1 (%)	0	0	0	2.15	8.6	8.6
	2 (%)	1.08	3.23	7.53	20.43	34.41	65.59
	3 (%)	45.16	2.15	5.38	53.76	43.01	23.66
	4 (%)	51.61	39.78	43.01	20.43	13.98	2.15
	5 (%)	2.15	54.84	44.09	3.22	0	0
≥4 percentage		53.76	94.62	87.1	23.65	13.98	2.15
≤2 percentage		1.08	3.23	7.53	22.58	43.01	74.19

the multimedia classroom. Since clarity and comfort themselves vary from person to person, it is a relatively subjective concept. At present, there is no clear regulation on the brightness value in the field of vision of the multimedia classroom, which is the value of visual clarity and visual comfort [18]. Therefore, taking visual comfort as an example (the same can be used for visual clarity), this paper proposes a threshold limit value of 50% obtained when the subjective evaluation score is greater than or equal to 4, which is a higher standard value of visual comfort for the brightness parameter of the light environment in multimedia classrooms; when the subjective evaluation score is less than or equal to 2, the 50% threshold limit value obtained is the value that starts to cause visual discomfort.

4.1. Statistical Frequency Percentage. The statistical percentages of visual clarity and visual comfort under various experimental brightness parameters are shown in Tables 2 and 3.

4.2. Threshold Calculation. The calculation of the 50% threshold limit value obtained when the score of a large batch subjective evaluation experiment is greater than or equal to 4 is shown in Table 4.

We use the linear interpolation method to calculate the absolute threshold value and set the absolute threshold corresponding to the stimulation value in 50% proportion as X to obtain the following formulas:

$$\frac{400-300}{68.82-4.3}=\frac{X-300}{50-4.3}X=\frac{370.83\text{cd}}{m^2}, \tag{1}$$

$$\frac{600-500}{37.64-96.62}=\frac{X-500}{50-94.62}X=\frac{575.65\text{cd}}{m^2}. \tag{2}$$

Table 4: Calculation table of threshold limit value of visual clarity brightness change data.

Scoring frequency/percentage	Brightness parameters					
	300 cd/m^2	400 cd/m^2	500 cd/m^2	600 cd/m^2	700 cd/m^2	800 cd/m^2
≥4 percentage	4.3	68.82	94.62	37.64	3.23	0
≤2 percentage	48.39	3.22	0	22.58	76.34	98.92

Table 5: Calculation table of threshold limit value of visual comfort brightness change data.

Scoring frequency/percentage	Brightness parameters					
	300 cd/m^2	400 cd/m^2	500 cd/m^2	600 cd/m^2	700 cd/m^2	800 cd/m^2
≥4 percentage	53.76	94.62	87.1	23.65	13.98	2.15
≤2 percentage	1.08	3.23	7.53	22.58	43.01	74.19

Similarly, the threshold limit value of 50% visual acuity can be obtained when the score is ≤2, as shown in

$$\frac{400-300}{3.22-48.39}=\frac{X-300}{50-48.39}\quad X=\frac{296.44\text{cd}}{m^2}, \tag{3}$$

$$\frac{700-600}{76.34-22.58}=\frac{X-600}{50-22.58}X=\frac{651.01\text{cd}}{m^2}. \tag{4}$$

According to the calculation results of the absolute threshold value obtained by the above linear interpolation method, the 50% brightness threshold value obtained when the experimental score is greater than or equal to 4 is 370.83 cd/m^2 and 575.65 cd/m^2, respectively; the threshold limit values of 50% visual acuity obtained when the score is less than or equal to 2 are 296.44 cd/m^2 and 651.01 cd/m^2, respectively.

The threshold limit value of brightness change data for visual comfort is calculated in Table 5.

We use the linear interpolation method to calculate the absolute threshold value and set the absolute threshold corresponding to the stimulation value in 50% proportion as X to obtain the following formulas:

$$\frac{400-300}{94.62-53.76}=\frac{X-300}{50-53.76}X=\frac{290.8\text{cd}}{m^2}, \tag{5}$$

$$\frac{600-500}{23.65-87.1}=\frac{X-500}{50-87.1}X=\frac{558.47\text{cd}}{m^2}. \tag{6}$$

Similarly, the threshold limit value of 50% visual comfort can be obtained when the score is less than or equal to 2, as shown in

$$\frac{800-700}{74.19-43.01}=\frac{X-700}{50-43.01}X=\frac{722.42\text{cd}}{m^2}. \tag{7}$$

According to the calculation results of the absolute threshold value obtained by the above linear interpolation method, the 50% brightness threshold value obtained when the experimental score is greater than or equal to 4 is 290.8 cd/m^2 and 558.47 cd/m^2, respectively; the threshold limit value of 50% visual acuity obtained when the score is less than or equal to 2 is 722.42 cd/m^2. It should be noted here that due to the limitations of the range of brightness parameters in this experiment, when the score is less than or equal to 2, two thresholds have not been shown from the experimental results [19].

4.3. Analysis of Large Batch Subjective Evaluation Experiment Results. After comparing the brightness thresholds of visual sharpness and visual comfort of high and low standards, it was found that the difference between the values of high and low standards is large. Reviewing the field investigation and the analysis law of test data, the values of visual sharpness and visual comfort calculated in this experiment are taken as the values that can just reach clearer visual sharpness and poor visual sharpness, respectively; and the threshold point that can just bring better visual comfort and visual comfort is about to deteriorate [20, 21].

According to the definition of threshold and the above data rules, we can analyze the following.

4.3.1. Visual Clarity. When the experimental score is greater than or equal to 4, the 50% brightness threshold limit values are 370.83 cd/m^2 and 575.65 cd/m^2, respectively, that is, when the brightness range is 370.83 $cd/m^2 \leq X \leq 575.65$ cd/m^2, it has better visual clarity. When the score is less than or equal to 2, the threshold limit value of 50% visual acuity is 296.44 cd/m^2 and 651.01 cd/m^2, that is when the brightness range is $x \leq 296.44$ cd/m^2 and $X \geq 651.01$ cd/m^2, the visual acuity is poor. The average score of the visual acuity evaluation and the variation law of brightness are made into a trend analysis diagram, as shown in Figure 1.

4.3.2. Visual Comfort. When the experimental score is greater than or equal to 4, the 50% brightness threshold limit values are 290.8 cd/m^2 and 558.47 cd/m^2, respectively, that is, when the brightness range is 290.8 $cd/m^2 \leq X \leq 558.47$ cd/m^2, it has better visual comfort; the threshold limit value of 50% visual acuity obtained when the score is less than or equal to 2 is 722.42 cd/m^2, that is, when the brightness range is 722.42 $cd/m^2 \leq X$, the visual acuity is poor. The average score of the visual comfort evaluation and the variation law of brightness are made into a trend analysis diagram, as shown in Figure 2.

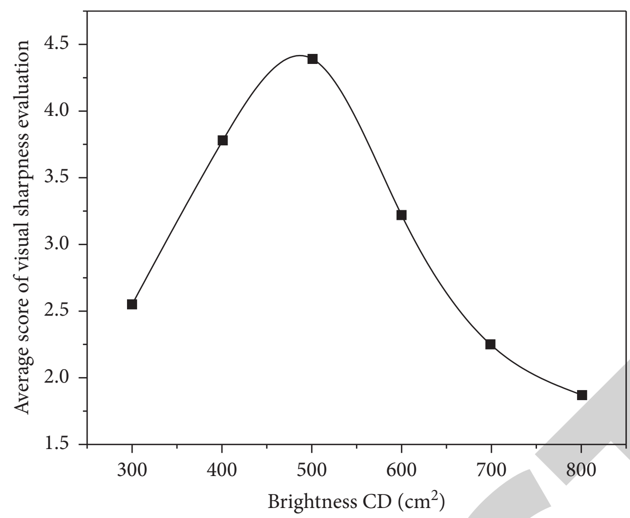

Figure 1: Analysis of average score and brightness change trend of visual acuity evaluation.

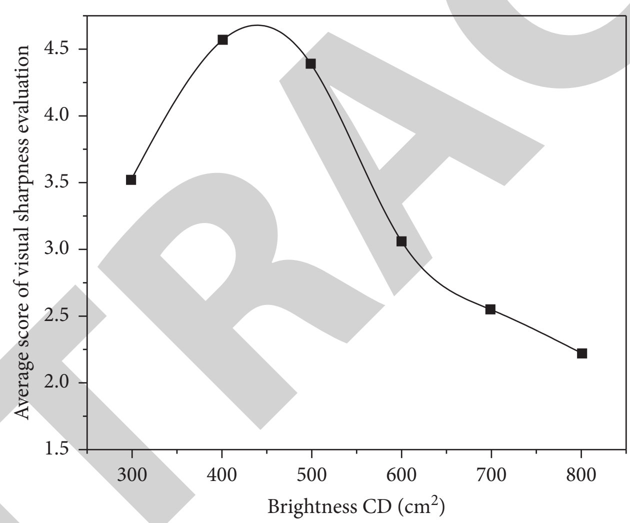

Figure 2: Analysis chart of average score and brightness change trend of visual comfort evaluation.

Table 6: Large probability distribution of brightness comparison data.

Brightness	300 cd/m^2	400 cd/m^2	500 cd/m^2	600 cd/m^2	700 cd/m^2	800 cd/m^2
Average brightness contrast	15 : 1	5 : 1	10 : 1	15 : 1	20 : 1	30 : 1

4.3.3. Luminance Contrast Value Distribution. From the above large batch of subjective evaluation experiments, according to the method described above, the value of the larger probability of the distribution of brightness contrast data is extracted as shown in Table 6, and its change trend is shown in Figure 3.

4.3.4. Interval Coincidence Part. From the above experimental data, we can analyze the overlapping part of the threshold interval, that is, the interval between good and poor visual clarity and visual comfort [22]. When the threshold value of 50% brightness obtained when the experimental score of visual clarity and visual comfort is greater than or equal to 4 coincides, that is, when the brightness range is 370.83 cd/m^2 ≤ X ≤ 558.47 cd/m^2, this classroom light environment has better visual clarity and better visual comfort at the same time. The threshold value of 50% visual acuity obtained when the experimental score is less than or equal to 2, that is, when 722.42 cd/m^2 ≤ X, this classroom light environment has poor visual acuity and comparative visual comfort at the same time [23]. Simultaneously, as described in Section 4, when the brightness contrast is close to 10 : 1, that is, when the brightness range is

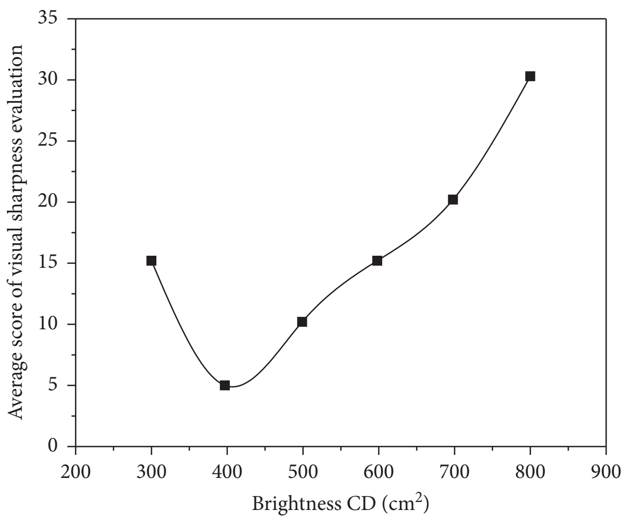

FIGURE 3: The numerical distribution diagram of the brightness comparison.

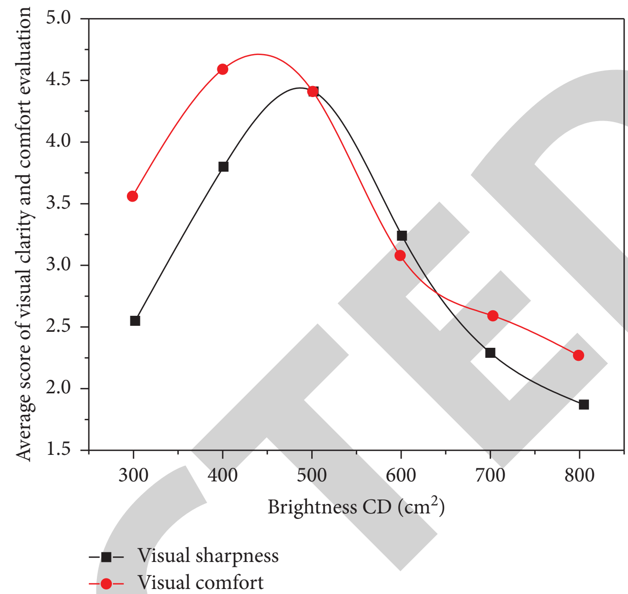

FIGURE 4: Relationship between brightness contrast and visual clarity and visual comfort.

$300\,cd/m^2 \leq X \leq 500\,cd/m^2$, the visual sharpness is the highest, and the visual sharpness decreases from side to side with the change of brightness contrast value; when the brightness contrast is close to 5 : 1, that is, when the brightness is close to $400\,cd/m^2$, the visual comfort is the highest. Similarly, the visual comfort decreases with the values on both sides. Shown in Figure 4 is the relationship between brightness, contrast, and visual clarity and visual comfort.

It can be concluded from the figure that when the brightness range is $370.83\,cd/m^2 \leq X \leq 558.47\,cd/m^2$, the light environment of this classroom has good visual clarity and visual comfort at the same time. In order to better reflect the coincidence interval of visual clarity, visual comfort, and brightness contrast within the same brightness range, the value of brightness contrast is reduced by ten times and their change trend is observed together with the average score of visual clarity and visual comfort [24]. The coincidence part of the threshold interval and the change trends of visual clarity, visual comfort, and brightness, as well as the comparative analysis diagram of brightness, are shown in Figure 5.

The overall change trend can be analyzed from the above change relationship. When the brightness range is $370.83\,cd/m^2 \leq X \leq 558.47\,cd/m^2$, the light environment of this classroom has good visual clarity and visual comfort at the same time. At this time, the brightness contrast value is low, which can reflect that when the brightness pair is relatively low, there will be better visual clarity and better visual comfort [25]. Here, we introduce the concepts of reference target value and current value and draw up the 50% threshold limit value obtained when the evaluation score in a large batch of subjective evaluation experiments is less than or equal to 2 as the current value required for future development. The 50% threshold limit value obtained when the evaluation score in a large batch of subjective evaluation experiments is greater than or equal to 4 is formulated as the target value that needs to be achieved for future development.

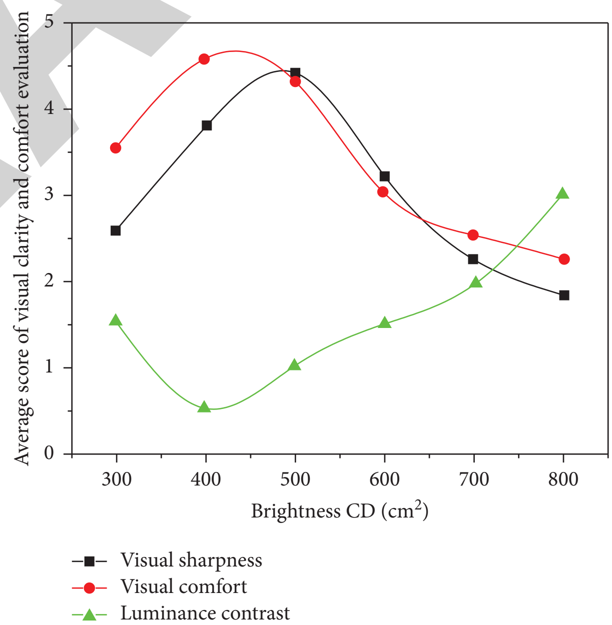

FIGURE 5: Comprehensive analysis diagram.

4.4. Influence of Brightness Change on Visual Subjective Evaluation

4.4.1. Change Trend. There is a strong correlation between the visual clarity and visual comfort of the light environment of multimedia classrooms in colleges and universities and the change in brightness, which directly affects the visual efficacy, visual experience, and subjective feeling. The selection of the evaluation factors for the light environment in the multimedia classroom space is the basis for determining the evaluation indexes in the following paper. According to

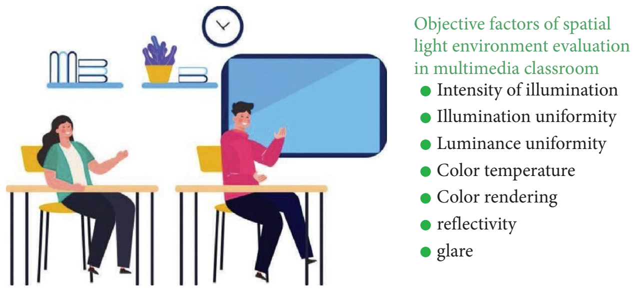

Figure 6: Composition of objective influence factors.

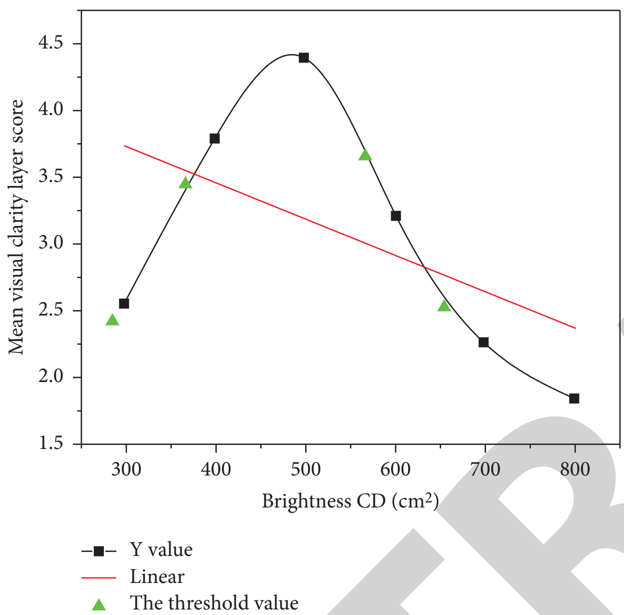

Figure 7: Variation trend of visual clarity and brightness.

the measurement of the light environment in the multimedia classroom space in colleges and universities and referring to the relevant norms and standards, the objective influence factors of the light environment evaluation in the main space are sorted out and analyzed, including illumination, illumination uniformity, brightness uniformity, color temperature, color rendering, reflectivity, and glare. Shown in Figure 6 is the composition model of the objective influence factors of the spatial light environment evaluation of the multimedia classrooms in colleges and universities. According to the relationship between brightness change and visual clarity and visual comfort, this paper makes a change trend chart according to the average score of the subjective evaluation and each threshold value, as shown in Figures 7 and 8.

As can be seen from Figures 7 and 8, the trends for visual clarity, visual comfort, and brightness parameters are roughly the same. When the brightness value is about 500 cd/m^2, the visual clarity is positively correlated with the change in brightness value; when the brightness value is about 500 cd/m^2, the visual clarity is negatively correlated with the change in brightness value; when the brightness value is about 400 cd/m^2, the visual comfort is positively correlated with the change

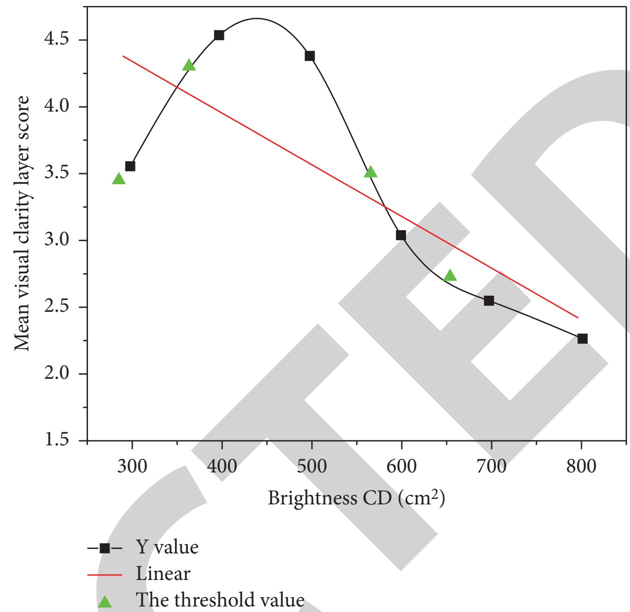

Figure 8: Variation trend of visual comfort and brightness.

in brightness value. When the brightness value is about 400 cd/m2, the visual comfort is negatively correlated with the change in brightness value. Although some change trends can be seen from the figure, the specific variable values are not clear and need further analysis.

4.4.2. SPSS Curve Regression. Curvilinear regression is a data analysis method that transforms according to the characteristics of the data, then performs linear regression or uses a curve fitting method to fit the original data to determine the curve regression equation.

This section studies the relationship between brightness parameter changes and visual clarity and visual comfort in multimedia classrooms in colleges and universities and uses software to perform curve fitting to find the quantitative relationship between brightness changes and visual clarity and visual comfort, finally determining the curve equation. Through the curve equation, the specific change trend can be analyzed, and the brightness values that make the vision the clearest and the most comfortable can be found, respectively, as well as the brightness values that need to be achieved to meet certain visual clarity or visual comfort.

Curve regression steps mainly include the following: First, we use the line chart to preliminarily judge the curve type. To reduce the blindness of curve estimation, it is necessary to draw a line chart first, and according to the change trend of dependent and independent variables in the line chart, you can choose an appropriate function to fit the data points. Then, we perform curve regression analysis. After the computer processing of curve regression is completed, the most appropriate curve regression type is selected according to the output results of the computer and the square value of the judgment coefficient R. Finally, according to the regression type of the fitted curve and the value of each coefficient, the functional formula is obtained.

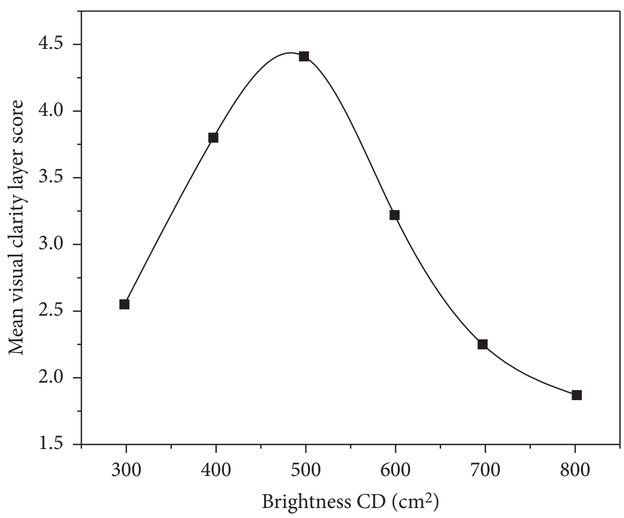

Figure 9: Line chart of brightness and visual clarity.

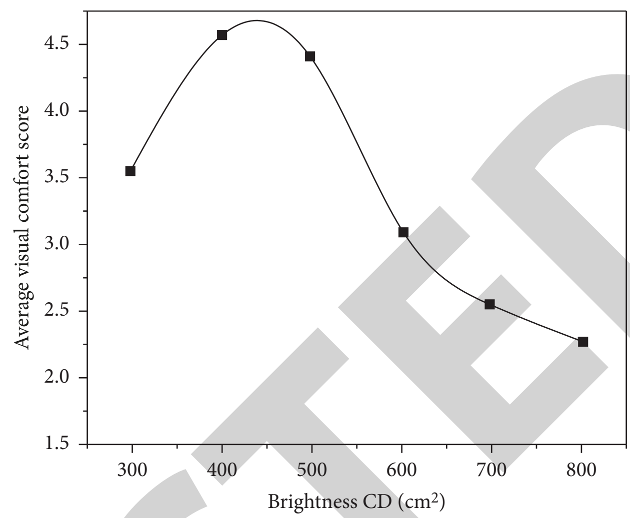

Figure 10: Broken line diagram of brightness and visual comfort.

(1) Draw a (X, Y) line chart of the relationship between visual clarity, visual comfort, and brightness parameters, as shown in Figures 9 and 10. The relationship between brightness, visual clarity, and visual comfort can be preliminarily observed, and the relationship between independent and dependent variables can be judged to be close to a curve. Therefore, curve regression analysis can be continued.

(2) Curve Fitting. According to the change trend of the line chart, the form of the curve is preliminarily judged and the quadratic function and cubic function are selected for fitting.

According to the definitions of the independent variable and dependent variable, the brightness value of the multimedia classroom is determined as an independent variable and the evaluation score of visual clarity or visual comfort is determined as a dependent variable.

The broken line diagram of the actual data of visual clarity and brightness and the fitting diagram of the quadratic cubic function curve equation are shown in Figures 11 and 12.

(3) Curve Fitting Is Carried Out according to the Data. From the data of the SPSS software model and parameter evaluation, it can be found that the R^2 values of the determination coefficient of the quadratic curve model and the cubic curve model are 0.788 and 0.962, respectively, indicating that the quality and fitting effect of the two regression models are relatively good.

The fitted quadratic function curve equation of visual sharpness and brightness is $y = -2.566 \times 10^{-5}x^2 + 0.026x - 2.546$.

The fitted cubic function curve equation of visual sharpness and brightness is $y = 1.121 \times 10^{-7}x^3 + 0.122x - 18.087$.

According to the actual situation and reviewing the experimental situation and the trend of experimental values, after the brightness reaches 800 cd/m^2, the trend of visual clarity should decrease with the increase in brightness, so the cubic function is excluded in combination with the figure

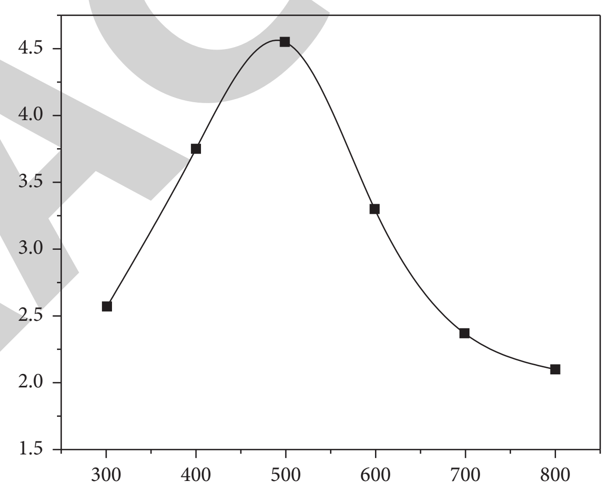

Figure 11: Line chart of actual data of visual clarity and brightness.

and the functional formula. At the same time, due to the definition of experimental scope, independent and dependent variables have actual scope areas, theoretically. In this area, if the quadratic function equation is used, the brightness value reaching the highest point of visual clarity can be calculated to be about 506.25 cd/m^2.

Similarly, the broken line diagram of the actual data for visual comfort and brightness and the fitting diagram of the quadratic cubic function curve equation are shown in Figures 13 and 14.

Curve fitting was carried out according to the data. From the data of the SPSS software model and parameter evaluation, it can be found that the R^2 values of the determination coefficient of the quadratic curve model and the cubic curve model are 0.771 and 0.979, respectively, indicating that the quality and fitting effect of the two regression models are relatively good.

The fitted quadratic function curve equation of visual comfort and brightness is $y = -1.42 \times 10^{-5}x^2 + 0.012x + 1.675$.

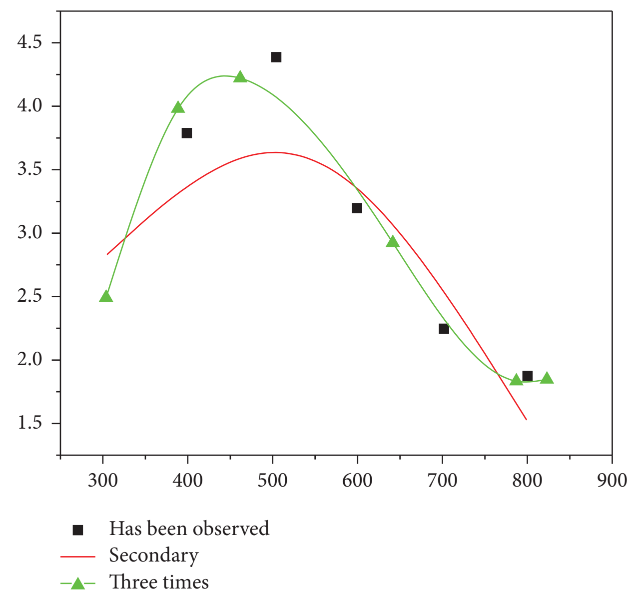

FIGURE 12: Fitting diagram of quadratic cubic function curve equation.

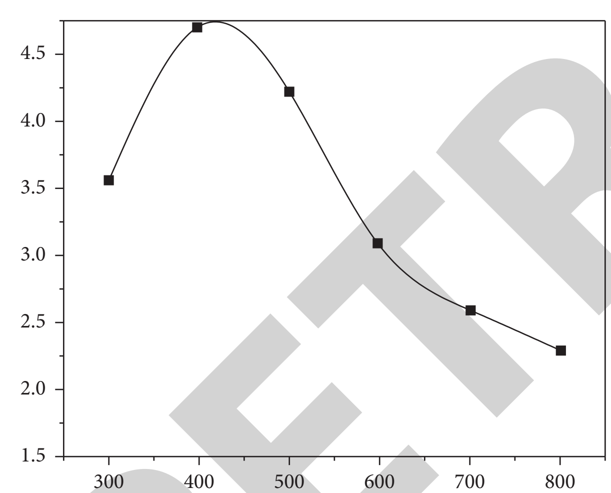

FIGURE 13: Line chart of actual data of visual comfort and brightness.

The fitted cubic function curve equation of visual sharpness and brightness is $y = 1.205 \times 10^{-7}x^3 + 0.115x-15.022$.

According to the actual situation and reviewing the experimental situation and the trend of experimental values, after the brightness reaches 800 cd/m^2, the trend of visual clarity should decrease with the increase in brightness, so the cubic function is excluded in combination with the figure and the functional formula. At the same time, due to the definition of experimental scope, independent and dependent variables have actual scope areas, theoretically. In this area, the brightness value reaching the highest point of visual comfort can be calculated according to the quadratic function equation, which is about 422.54 cd/m^2.

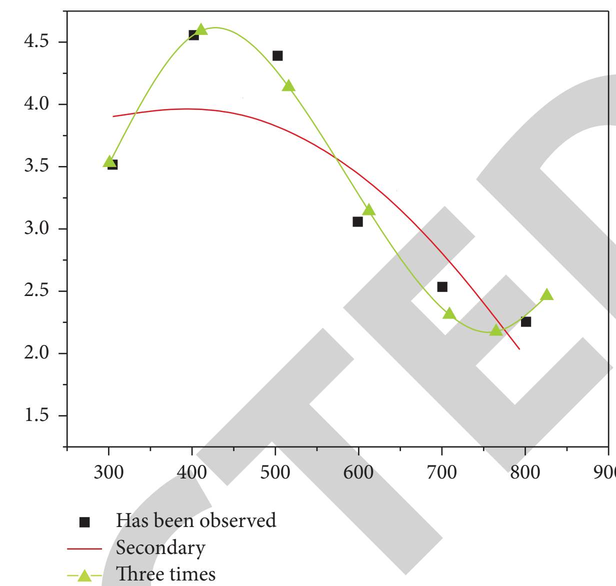

FIGURE 14: Fitting diagram of the curve equation.

5. Conclusion

This paper presents a method for extracting the light environment of a multimedia classroom by using high dynamic range images and puts forward a new method and idea for measuring the light environment. However, at present, the multiexposure method is used to obtain high dynamic range images, which stays at the measuring point for a little longer, and the information acquisition effect of dynamic scenes is poor. It is hoped that future research can improve the method of obtaining high dynamic range images or develop a more intuitive and effective method of extracting visual brightness closer to human eyes.

Considering the factors of healthy lighting, energy conservation, and environmental protection, in the treatment and selection of the light environment of the multimedia classroom, we should fully consider the use of natural lighting, adopt curtains that can adjust the transmittance of natural light, etc., so that the intensity and direction of natural light entering the classroom can be adjusted according to the demand, and combine these adjustment methods with light sensing devices to automatically adjust the amount of indoor light and lighting light.

The white plastic curtain used in this study belongs to the screen of reflective light source type and uses static visual recognition objects. In the actual teaching environment, there are also multimedia teaching tools with self-illumination and different dynamic playback frequencies, such as LCD and electronic whiteboard. The specific impact degree and impact law of these equipment need to be further studied.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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