Study on Residential Smart Lighting under the Perspective of Light and Space

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Abstract. Focusing on the current residential lighting, it does not meet the basic lighting function, and ignores the residents' visual and psychological acceptance. Its insufficient brightness severely violate people's lighting life. In response to this problem, this article discusses intelligent lighting theory around the internal atmosphere of the theme from the perspective of light and space, with communities and people as the main body. The idea that lighting should be centered on people was proposed. The relevant evaluation model was used to provide data support by this paper for strengthening internal functions from the perspective of community space, the improvement of the internal atmosphere of the community was completed and the conflict between the lighting and people's emotions were eventually eased.

1. Introduction
With the continuous development of the lighting industry, people have a deeper understanding of light, and the rational use of light to serve people's production and life has become a common consensus\textsuperscript{[1]}. Human's longing for light has led to the development of the lighting industry. With the rapid development of technology, intelligence, wisdom, and integration into the lighting market, from devices to equipment to products, the entire process is accompanied by intelligent production and intelligent applications. While realizing convenient lighting, a deeper level of understanding and understanding of the concept of "light" has been tapped, so a new value space has emerged, which is to use light reasonably and smartly to serve people's lives.

Bright light seems to be the entry criterion for smart lighting, seeking a quiet and comfortable light life also seems to be a luxury\textsuperscript{[2]}. In response to this problem, taking the public environment of the community as the research background, focusing on the internal environment to strengthen the navigation and landscape functions, using the evaluation model to establish a connection with the navigation function, providing a guiding theoretical basis for the calibration of light sources, objectively quantify people's visual needs for lighting, and indirectly ease the contradiction between human emotional logic and lighting entities.
2. Residential lighting background research

2.1. Community road attributes

2.1.1. Category attribute.
There are many types of roads in the community's public environment: distribution roads at the entrances and exits of the community, mixed roads of pedestrian walkways and motor vehicle lanes between floors, and regional roads in the leisure areas of the community. The walkway environment in the community mainly takes pedestrians as the service object, and provides a road environment that is convenient for pedestrians to enter and leave the residence or take a leisure walk. Through the observation of the road environment of the community and the comparative analysis of the lighting quality data, the general width of the community walkway and the settings of the height and spacing of the light sources can be determined.

2.1.2. Lighting properties.
Most of the residential roads are residential pedestrians. The service objects of lighting design are mainly for pedestrians. The design concept is more specific and the product functions are more detailed. It needs to meet the needs of residents' personalization and comfort. Therefore, different road categories should be equipped with lighting indicators and programs that meet the corresponding social logic and emotional logic.

2.2. Current status of landscape lighting.

2.2.1. Lighting design is an important method of spatial expression.
Under the premise of satisfying functionality, it has gradually paid attention to the needs of people's physical and psychological levels, and it has been artistically expressed. At present, there are two problems in landscape lighting in residential areas.

Firstly, the brightness uniformity of the landscape lighting is not enough, and too high illuminance in some areas will cause glare and affect the rest of the residents. The lack of uniformity of brightness and glare in the landscape lighting of the community gives residents a blind sense of nowhere to look, which cannot form a progressive emotional introduction, and the attraction and interest of the landscape will be affected \cite{3}.

Second, the landscape lighting has a single form, the lighting in the community public environment should be based on environmental characteristics and surrounding buildings, plants, water, etc. Form a multi-level transitional three-dimensional lighting. The outline formed by the light and landscape elements in the walkway formed a dense visual experience and conveying overwhelming visual information \cite{4}.

3. Research on the wisdom concept under the relationship between light and space

3.1. Exploration of lighting concept

3.1.1. Explanation of visual characteristics.
Vision is a physiological vocabulary. Light acts on the visual organs to make them feel excited by the cells, and the information obtained is processed by the visual nervous system to produce vision \cite{5}. Vision includes two major parts of acceptance and cognition, namely visual perception and visual perception. Visual perception is responsible for perceiving the existence of light and objects. Visual perception is responsible for the aesthetic, interpretation and evaluation of the meaning of objects in the brain, which belongs to the high-level cognitive part.

Reflected in the current status of the community, the monotonous lighting allows residents to get the most direct visual landscape experience. Their visual perception has a consistent degree of
aesthetic identity, and visual perception affects the evaluation and interpretation of the meaning of things due to individual experience differences. Lead to very different psychological feelings. The key to intelligent lighting of community trails is the conversion of sensory language and parametric language\[6-7\]. How to weaken individual experience differences, detect group psychological feature perception or rely on significant individual feature sets to qualitative groups, and maintain a certain degree of matching is very practical research.

3.1.2. Evaluation of visual experience.

The logical framework is summarized according to the current situation of the residential landscape lighting. As the basic theoretical basis of visual evaluation experience, the logical framework is shown in the figure below.

![Figure 1. The logical framework of residential lighting](image)

As shown in Figure 1, in the current situation of residential landscape lighting, various technical parametric problems have led to differences in people's subjective perceptions in vision. All lighting quality parameters have formed a visual experience in the vision. Based on the research methods of perceptual engineering, combined The parameters reflected in the environment are used to study the visual characteristics of people, and the landscape lighting concept about the trail environment is generated. In this logical framework, taking the basic visual characteristics of people as an entry point, elaborating visual concepts and characteristics, analyzing the functional characteristics of landscapes and pedestrians in the visual process, detecting group psychological characteristics and feelings, and targeting people with certain professional backgrounds, you can The use of lighting quality evaluation methods and the quantification of human visual psychology to establish the directionality and subjective professional evaluation results, to establish a foundation for the integration of a comprehensive social evaluation.

3.2. Verification of the evaluation model

3.2.1. Intermediate Vision.

The visual efficiency function $V_{mes}(\lambda)$ of the human eye spectrum light in intermediate vision is different from that in the bright (dark) vision\[8-9\], as shown in Figure 2 The spectral light visual efficiency function $V_{mes}(\lambda)$ described in the new intermediate vision system (as shown in Figure 2, $V_{mes}(\lambda)_{1}$, $V_{mes}(\lambda)_{2}$, $V_{mes}(\lambda)_{3}$) is the visual light vision Linear combination of efficiency function $V(\lambda)$ and dark vision light efficiency function $V'(\lambda)$. 
The fields related to intermediate visual lighting include road and street lighting, outdoor and other night traffic lighting, etc. [10]. The current regulations and standards for road lighting are also determined based on research under bright vision conditions. In the community trail environment, serving external pedestrians should fully consider the visual characteristics under intermediate vision conditions, so that the light source can produce greater visual performance in the intermediate vision category. Only on the basis of safety and comfort can the navigation function of the extension of the light source be fully utilized, and the direction of pedestrians outside the community can be pointed out in the appropriate lighting effect, and the addressing and tracing can be accurately performed.

3.2.2. Photobiological effects.
There is a third type of photoreceptor cells on the human retina. These cells control many non-visual biological effects, such as circadian rhythm, melatonin secretion, and alertness [11]. Human life state has different needs for light at different times. This applies to the characteristics of the photobiological effect, which affects the alertness and drowsiness of the human body. It has a greater safety issue that should be considered by outside pedestrians walking on strange trails. The significance of the study [12], so it is particularly important to add an exploration of the biological effects of non-visual light in the concept of external navigation.

3.2.3. Objective quantitative evaluation.
The different light color atmosphere of the light source brings different psychological feelings. In the aspect of intermediate vision, the parameter value unilaterally considers the spectral light visual performance of the light source, and through comparison, it can be concluded which light source can produce a better lighting effect; non-visual aspects, two The parameter value of this evaluation model comprehensively considers the efficacy of the light source and the degree of inhibition of melatonin [13-14], which gives people a sense of alertness or ease. Community walkway lighting needs to provide different atmospheres for different groups, internal residents should be comfortable and comfortable in the landscape function, and external pedestrians should be vigilant and precautionary in the navigation function to solve the navigation effect of the environment on external people, and in turn reflect the image of the community. To improve public evaluation and complete the closed loop from internal atmosphere to external evaluation.

4. Quantitative verification analysis

4.1. S/P value evaluation model
According to the analysis of the optical performance function X model and the MOVE model of the intermediate visual spectrum: when the S/P value is less than 1, the conversion factor of the bright visual brightness in the intermediate visual brightness shows an exponentially increasing trend; when
the S/P value is greater than 1, the conversion coefficient shows an exponentially decreasing trend \[15\]. This shows that when the S/P value is higher, the spectral light viewing efficiency of intermediate vision is higher, and the increasing trend will gradually slow down as the value increases.

\[
\frac{S}{P} = 1700 \int_{\lambda_3}^{\lambda_8} P(\lambda)V'(\lambda)d\lambda \cdot \left[ 683 \int_{\lambda_3}^{\lambda_8} P(\lambda)V(\lambda)d\lambda \right]^{-1}
\]

Among them, \(P(\lambda)\) represents the relative spectral energy distribution of the measurement light source, \(V(\lambda)\) and \(V'(\lambda)\) are the bright and dark vision light efficiency functions \[16\].

4.1.1. Evaluation model of circadian stimulation CS value.
The circadian stimulation evaluation model (CS value) comprehensively considers the spectral light efficacy \(M_\lambda\) of melatonin containing retinal ganglion cells, the large field L+M cone cell spectral light efficacy \(V_{10\lambda}\), and the rod cell spectral light efficacy \(V'\lambda\), S cone cell spectral light efficiency \(S\lambda\), the spectral irradiance obtained by the human eye \(P_\lambda\) \[17\]. Therefore, the CS value can more comprehensively evaluate the non-visual light biological effect of the light source, and the calculation method is as follows:

\[
CS = 0.75 - 0.75 \cdot \left[ 1 + \left( \frac{CL_A}{217.75} \right)^{0.864} \right]^{-1}
\]

\(CL_A\) is the normalized result of day and night light (CL), and the size characterizes the inhibition of melatonin, thus reflecting the strength of the photobiological effect \[18\].

4.2. Data processing
In order to compare the intermediate visual effects and non-visual photobiological effects of the lighting source, fluorescent lamps and LED lamps at different color temperatures and powers were selected to carry out photobiological effects evaluation experiments. The experimental device and process are shown in Figure 3.

![Diagram of experimental setup](image)

Figure 3. Relative spectrum of typical light source

220V 50HZ provides the drive for the light source, the current is transferred from DC to AC in the spectrum analyzer, the spectrum chart is measured using software, and the relative intensity data at each wavelength is collated, as shown in Figure 4.
Use MATLAB calculation software to obtain the S/P and CS values of the illumination spectrum light source, as shown in Table 1.

| Lighting source                  | S/P value | CS value |
|----------------------------------|-----------|----------|
| LED (6500K 4W)                   | 2.06      | 0.56     |
| LED (6000K 5W)                   | 2.05      | 0.49     |
| LED (6500K 5W)                   | 2.11      | 0.54     |
| LED (6000K 6W)                   | 1.94      | 0.48     |
| LED (3000K 7W)                   | 1.39      | 0.25     |
| LED (6500K 7W)                   | 2.34      | 0.56     |
| Fluorescent lamp (2700K 4W)      | 1.19      | 0.27     |
| Fluorescent lamp (4000K 9W)      | 1.60      | 0.39     |
| Fluorescent lamp (6500K 15W)     | 2.05      | 0.47     |

It can be seen from the table that in terms of intermediate vision, high color temperature fluorescent lamps and LED lamps have higher S/P values, which can produce greater spectral light visual performance in the intermediate vision category, compared with other lighting sources. Can produce better lighting effects, help to achieve a comfortable and comfortable lighting atmosphere, integrate people's emotional logic and the connection of lighting entities, better serve internal residents, and reflect the importance of serving people. In terms of non-visual aspects, high color temperature fluorescent lamps and LED lamps have higher CS values, which have a greater inhibitory effect on human melatonin, can enhance people's alertness, and are conducive to providing safe and better visually-oriented lighting Features.

Summarize the logical framework in the exploration of the community lighting background, put forward the concept of community lighting with people as the core, and then use human vision as the entry point for research, and validate the valid data obtained after quantitative verification to reasonably ease the contradiction between human eyes and light. People provide effective support for the core concept.
5. Conclusion
The article organizes an overview of the development process of lighting, completes background research on the specific trail environment of the community, and proposes the concept of lighting based on the current situation. The logic from the outside to the inside solves the reality of lighting. A research method combining environmental attributes and human visual psychological characteristics as an entry point is proposed, and the feasibility of smart lighting of community trails is explored around the human-centered subject. According to the spectral properties of the light source, combined with the intermediate vision and photobiological effect evaluation models, the quantitative data of the people's visual psychology is obtained, which provides a guiding theoretical basis for the selection of light sources in the community's walkway environment. In the framework of the relationship between light and space, the relationship between lighting and human emotions is improved, which is conducive to the comprehensive optimization of the community lighting from the internal atmosphere to the external evaluation.

Acknowledgments
Thank you tutor for your professional guidance during the research process. During the research process, the instructor provided valuable opinions on the understanding of professional concepts, the construction of the logical structure of the article, and the details of the thesis, which cultivated good research habits for me and laid a good foundation for my subsequent research. Is also the key reason why I can successfully complete the thesis. I would also like to thank the seniors for their help in the research process, helping me overcome many difficulties and successfully complete the thesis.

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