Research on Museum Lighting Design Method: Emotional Effects Based on the SVOE Model and Creative Thinking

Zhisheng Wang[1 2], Yukari Nagai[1], Nianyu Zou[2], Ting Liu[1], Zhi Sun[2], Jiahui Liu[2]
[1] Knowledge Science, Japan Advanced Institute of Science and Technology
Nomi, Japan
[2] Research Institute of Photonics, Dalian Polytechnic University
Dalian, China
E-mail: s1820006@jaist.ac.jp, ynagai@ jaist.ac.jp

***Abstract*— Through the interdisciplinary integration of multidisciplinary majors and the study of creative thinking, this paper combines theories of architecture, design, optics, and psychology to propose a lighting design method based on visual factors and propose a theoretical model of lighting design based on "SVOE," through the use of creative thinking. As a function of the evolution of spatialization, visualization, optical indexing, and emotionalization, the theoretical model of lighting design innovates on the thought processes and evaluation of lighting design. Based on research related to LED light source lighting design methods, the design of humanized emotional lighting that considers functional rational lighting design as well as human emotions has emerged as an urgent problem that must be addressed. This paper applies psychological theory and research systems to approach emotional lighting design and practice through emotion analysis design methods based on spatialization, visualization, optical engineering, and psychology. The process of lighting design entails the transformation of a 'definition concept' and a 'solution concept', whereby information is transferred from the concept idea to drawing practice. This type of design conceptualizes and defines concepts, ultimately transforming them into a solution. The results of this study are expressed in design drawings and architecture spaces.**

Keywords—Creative thinking; Museum lighting design; Spatialization; Visualization; Emotionalization

I. INTRODUCTION

In 2011, the 27th International Lighting Commission Conference was held in Sun City, South Africa. Indoor lighting quality, light health illumination, and glare control became the focus of the branch for which the theme was the indoor environment and lighting design.[1] The research on the relationship between emotion and design includes different theories and the practical progress is characterized by different angles, forms, and methods in Western countries. [2] Japan's sensible engineering theory is one of the representative studies. This theory originated when researchers at the Faculty of Engineering of Hiroshima University in Japan began to consider the emotions and desires of occupants in their homes and introduced emotional analysis into the field of engineering to enable research on how occupants' sensibilities could be transformed. This was originally referred to as "Emotional engineering". [3]

Creative thinking is a way of thinking which, through the process of understanding, promotes the generation of new ideas and perspectives through analysis, synthesis, comparison, abstraction, and reasonable imagination.[4] The formation of new concepts in traditional lighting design methods is the key to innovative lighting design. The environmental lighting of architectural spaces has been called the fourth dimensional space of architecture. However, one of the key reasons for this is the invention of artificial light sources. With the development of the LED light source, its excellent characteristics of volume, color temperature, brightness, color rendering and controllability make it the most ideal light source carrier. Thus, as lighting technology is rapidly developing, lighting design concepts and methods should also be improved and promoted.

Scientific thinking has an important guiding role in the practice of innovation. To be innovative, creativity is needed and creative thinking is one of its core components. Combining creative thinking with lighting design techniques and applying this combination to the development of new environments and design processes can allow innovation to become more efficient. This is the starting point of our research. This paper provides summaries and explorations on the regularity of thinking and the characteristics and principles of lighting design. Furthermore, creative thinking and the auxiliary function of innovative design methods are analyzed from various angles. Through to research for innovative lighting design methodology has also made a certain induction.

II. INNOVATION LIGHTING DESIGN METHOD

The LED light source has been widely popularized in museum lighting because of its excellent characteristics, such as energy efficiency, environmental protection, and the controllable spectrum. These are characteristics that the traditional halogen lamp and fluorescent lamp do not possess.[5] It has become a potential lighting source for a new generation of museums and galleries. Experiments and discussions on the color quality of LED lighting applications in museums have been conducted frequently in the

international academic arena. The feasibility of museum LED lighting has been verified. Objectives have been established, such as building a light environment that viewers can appreciate and developing the feeling and emotion generated by light into a method of lighting design, which puts higher requirements on the method of lighting design itself.

A. Explicit Thinking and Tacit Thinking in Innovative Lighting Design

Traditional lighting design only considers the basic lighting requirements of spaces and exhibits and has not considered the influence of spatial visualization conditions and emotional feelings. This study uses creative thinking to conduct interdisciplinary of lighting design processes and related disciplines. By using the lighting design theory, "SVOE" mode, to influence the viewer's mood when visually perceiving a space, a solution related to the relationship between people, space, and light will be proposed. Two kinds of human knowledge, i.e. explicit knowledge and tacit knowledge, are used in this research.

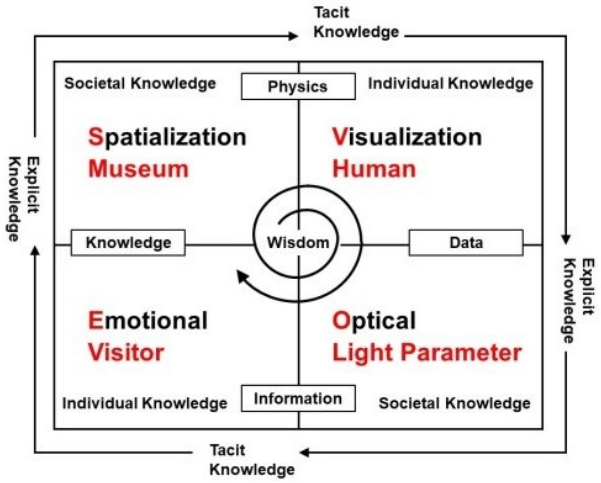

Fig. 1. "SVOE" mode lighting design analysis chart

Explicit knowledge, also known as direct knowledge, refers to knowledge that can be clearly expressed, and is usually described as knowledge that can be expressed in written words, diagrams, and mathematical formulas. In "SVOE" mode, space and optics are part of the body of explicit knowledge. Knowledge that one cannot clearly express is called tacit knowledge. Visual perception and psychological experience are part of Tacit Knowledge. (**Fig. 1.**)

B. Methods and Principles of Innovative Lighting Design

Spatialization is the digitization of design carriers and the classification of architectural spaces and exhibit types by analyzing the physical space of museums. Through the use of the principles and methods of architecture, the space of the museum can be clearly defined and the physical properties and functional scales of the space can be sorted and classified. For example, by digitizing the length, width, and height of the building space, the orientation and size of the windows can be simulated.

At that point, the spatial properties and art type of the museum are classified. For example, the flat paintings in the museum are classified based on method (such as ink painting, oil painting, gouache, printmaking, printing and dyeing, etc.) and age. The disciplines and professions are classified through uniform criteria, so the space and the exhibits in the museum can be turned into explicit knowledge. The spatial data parameters that are measured are set as invariants in the lighting design model.

Visualization is the analysis of the visual factors and sensory factors of the human experience. The visual factors in the human senses determine how much information is received by humans in the world. The quantity of images perceived by each person is different. Furthermore, there are many other differences among people, such as belonging to different age groups, and academic level or artistic experience, which which add even more uncertainty to the definitive characterization of people's visual factors. Thus, visualization in the museum is divided into tacit knowledge and factors of visual influence, which are set as variables in the lighting design model.

Optical engineering belongs to the category of natural science. The evaluative indicators of visible light in optics mainly include illumination, color temperature, color rendering and environmental contrast. By simulating and changing the lighting parameters in space, an analysis of the illumination environment in the exhibits in different spaces becomes possible. Through analysis of the factors of visual influence for different types of people, the optical parameters in the museum become the most important factor affecting visitors' viewing mood. Indicator parameters, the parameters which govern the way emotions are affected, have a clear definition, and provide a reliable condition for the final emotional response map. The techniques and principles of optical engineering are typical explicit knowledge, which set optics as invariants in the lighting design model.

Emotionalization is the ultimate indicator of the lighting design model. The first three indicators in the model are to create a light environment suitable for the viewer's emotions. The traditional lighting design does not consider human emotional factors, and only considers the functional problems of lighting in space. It only addresses functional problems and does not consider people's emotional requirements for different spaces. Through the lighting design which results from the "SVOE" mode, spatial, visual and optical considerations are comprehensively considered, which enables the realization of emotional evaluation maps for different types of people, thereby making it possible to build different types of light environment spaces.

III. SPATIAL RESEARCH ON MUSEUM LIGHTING DESIGN

This research focuses on innovative theoretical research related to museum lighting design, which generally considers four elements: spatialization, visualization, optical engineering, and emotionalization. “Spatialization” research in innovative lighting design focuses on the physical analysis and categorization of space and exhibits.

At present, there are different perspectives related to the relationship between Lighting Design and the Spatial Environment, and between the understanding of architecture and interior design.[6] Lighting design is a visual medium and language that can be displayed by the indoor spatial environment. Using light, people can perform the basic perception activity of observing its effect on the indoor environment, which then prompts other senses and behaviors in the indoor environment. Through different light designs, the indoor environment can produce a change in the spatial effect.

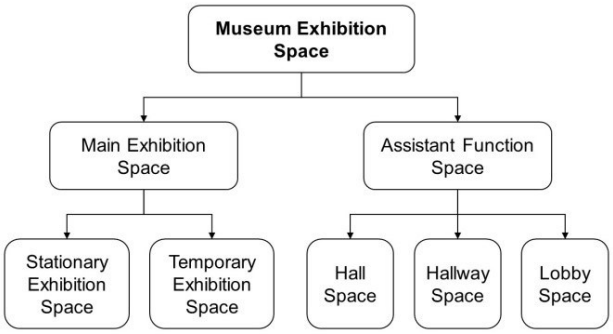

Fig. 2. Museum exhibition space classification map

A. Spatialized Functional Classification

The museum building belongs is classified as a public building. The functional division and traffic flow layout in the building space are complex. The museum building space is divided into display and auxiliary spaces, based on the function of the display. The exhibition space is divided into permanent exhibition space and temporary exhibition space. Each museum has a permanent exhibition that conforms to its own regional culture, as well as temporary exhibitions that are regularly changed. The basic layout of the permanent and temporary exhibition halls is similar. While the permanent exhibition hall will not change its lay-out, the temporary exhibition hall can have different spatial layouts for different types of exhibitions. Different types of exhibitions have different requirements for lighting. The light environment of the permanent exhibition hall will not normally change. The temporary exhibition hall will be redesigned according to the spatial needs of the exhibits. Therefore, the lighting and debugging requirements of the temporary exhibition hall are higher, and there is a need for technical parameters required for lighting which can be controlled and adjusted. (**Fig. 2.**)

The auxiliary space is the area that connects the display space, and generally includes the entrance hall, the preface hall, and the corridor space. The auxiliary function space does not include the exhibit warehouse and office space. The lighting design of these auxiliary spaces has a close correlation with the lighting environment of the exhibition space. The visual lighting design of the auxiliary space can affect the light environment of the exhibition space. Faced with such diversity within the building space, the light environment requirements of the building space are also high, and each space must be provided with a light design that meets the specific environmental requirements of that space.

The light environment evaluation index of the museum display space, if considered from the functional point of view, usually needs to meet three basic functions, and puts high requirements on the light color quality of the light environment. First, the lighting should meet the space display function, which requires space lighting to achieve a higher visibility for exhibits. This index is related to the illumination, fidelity, and color gamut. Second, the lighting should satisfy the preservation and maintenance functions of cultural relics or artworks. This requires the minimization of damage to the artifacts caused by illumination. The ultraviolet and infrared spectral components of traditional light sources such as halogen lamps and fluorescent lamps are the most harmful. In contrast, LED light sources can more easily regulate the spectrum to reduce harmful bands. Third, lighting should meet the requirements of research and educational functions. For example, the lighting for the restoration process of cultural relics in the workbench environment needs to achieve maximum fidelity, affecting the museum's LED lighting and the spectral characteristic parameters of the quality of color rendering.

B. Spatial Narrative Streamline

Every display space in the museum tells a story to its visitors. As there are different types of exhibits and display conditions in the exhibition space, each story requires a different light environment, to allow the creation of a particular atmosphere. Moreover, the light environment also needs to allow for changes in strength and rhythm, reflecting different feelings through changes in the light environments.

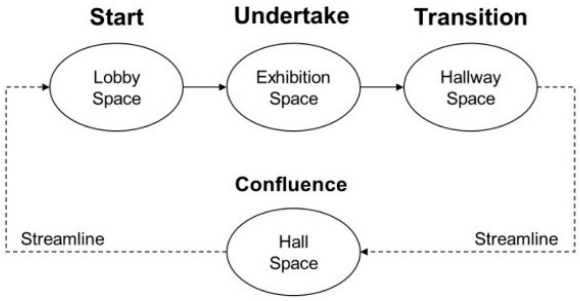

Fig. 3. Browsing process diagram of the museum exhibition space

The preface hall is the space in the exhibition that is first experienced by the visitors. It belongs to the space where the exhibition hall tells a story. The light environment in this space should create a suitable space for illumination. It should satisfy the visitor's visual perception and provide relief for the vision and psychology of the visitor. The illuminance of this space should be understood as the beginning, a "starting" point and cause of the story, and a display space tells the beginning of a story. The preface hall is one of the most important sections of the entire museum space, and it is also the largest. It belongs to the "bearing" stage and is the most important process in the whole story for a visitor. The corridor space is the space which must be passed through to return to the museum hall after a specific exhibition is over. This space is necessary for the appreciation of the process, soothing the

emotions of the visitors following their experience, and serving as a connection space, which is necessary to facilitate the "turning" point in the viewer's browsing process. (**Fig. 3.**)

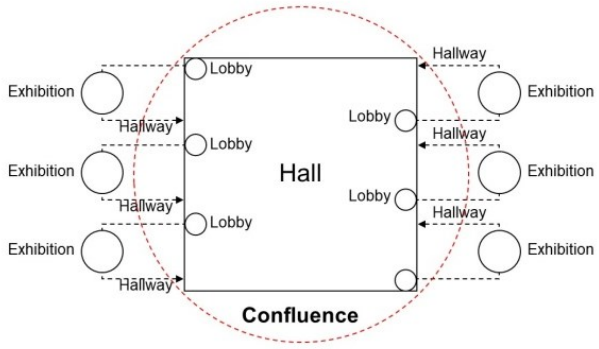

Fig. 4. Streamlined diagram of the museum exhibition space

The lobby space is the place to which visitors must return after the visit. The hall connects all other exhibition spaces. It is especially important to create a light environment which has suitable illumination and allows visitors to continue their visit. The hall here is a space of "convergence", the end of the story of a certain exhibition hall, and the beginning of the next story. Through the spatial layout of the museum, regional analysis and the streamlined design of the space can be carried out and combined with creative thinking to improve and enhance the planning methods for lighting design in the museum space. (**Fig. 4.**)

IV. VISUALIZATION STUDY OF MUSEUM LIGHTING DESIGN

Consider the lighting design of visual factors from the perspective of the layout and design flow of the building space. Vision is divided into bright vision, intermediate vision and dark vision. The time required for the various visual transformations is different. The layout of the space structure is planned and a suitable light environment is created through the transformation of the bright, dark and middle vision, to allow the visitors to feel more comfortable. By taking the principle of light and dark vision and the illumination relationship between the hall, the preface hall, the corridor, and the exhibition hall into account, it becomes important to design the relationship between light and dark and to integrate visitors' adaptation time to different visions as a design factor.

A. Bright and Dark Vision in Visualization

Considering the different visual factors of people in terms of illumination, we must first have a certain understanding of visual imaging. Vision is the process of observing things through the eyes. Vision is the sensation of light passing through the rod and cone cells in the retina and are the most critical components.[7] This information then passes through the optical nerve to the visual center and the brain for final image processing. The color in the light is very important for evaluation of quality lighting. The evaluation of light in optical engineering primarily depends on illuminance, color temperature, color rendering index, and color tolerance.

B. The Application of Visualizations to Lightness

The role of lighting design in indoor spaces is crucial. Therefore, we should pay more attention to the non-material information transmitted by these spaces, as it influences our psychological and emotional experience. Emotional design is based on "people-oriented" design and is based on the design concept of affecting people's emotional reactions. This research attempts to embed the concept of emotional design into indoor lighting design to meet the emotional needs of users in indoor environments. The design of an indoor environment experience which creates pleasant emotions is the goal of lighting design. Emotional design recognizes and analyzes the emotional connection between users, indoor environments, and lighting, and expounds on this aspect of emotional expression in lighting design. Emotional design proposes various principles and methods for indoor lighting, in order to provide references to improve current lighting design concepts and practices.

C. Application of Visualization to Prosody

Visualization is the recognition and understanding of human physiological indicators. [8] In approaching visualization in research, basic concepts and influencing factors of visual lighting design are analyzed from the perspective of individual physiological visual factors. By analyzing the process of people's visual experience in an indoor environment, based on visual theory that is combined with the characteristics of lighting design, one can construct the visual needs of an indoor environment's users. Through the analysis of questionnaires and evaluation indicators, a logical relationship has been established between psychology, optics, architecture, and design.

The impact of the visual sense on psychological feelings has been confirmed in other spaces. For light in classrooms, hospitals, and offices, it has been proven that light environments can change people's emotions and have an important impact on learning, work, and health. [9] The museum is a public place for visitors to obtain cultural information. There are many types of exhibits in this space. Therefore, logically, this space needs to be adjusted using the technical parameters provided by optical engineering. By designing the lighting carrier, one can create an environment with different illuminations and contrasts. In the selection of the lighting fixture and by choosing a suitable luminaire for color temperature and color rendering to display the lighting carrier, the visitor is able to experience more comfortable lighting and, as such, to have a better psychological viewing experience.

V. EMOTIONAL RESEARCH ON MUSEUM LIGHTING DESIGN

Emotional elements of lighting design include the analysis of spatial perception, contrast, and color rendering. By collecting data on the illumination, color temperature and color rendering of the museum exhibition hall, the most suitable environmental contrast and the most functional lighting can be determined. The diversity of lighting in the exhibition space considers the psychological feelings which result from various modes, such as backlighting, face lighting

and integrated lighting. Psychology divides the human brain's sensory thinking process into three levels of processing: visceral level, behavioral level, and reflective level. These three levels define the range of a person's emotions, from a low-level to a high-level. Analysis from the perspective of psychology shows that when people see things, their first feeling is on the visceral level. An emotions of viewing and experience is a person's initial emotion, a low-level emotion that is then followed by a behavior, and finally by reflection, which is the highest level of human emotion.

A. Emotional Attribute Definition

The visceral level involves the most basic physiological needs, and is therefore associated with the most basic functional lighting design. " Visceral, behavioral, reflection" appropriately define the three existing forms of emotion in lighting and highlight human emotions. After introducing the ideology of "human emotion based" into the field of emotional lighting, the "SVOE" model of innovative lighting design is perfected, and it becomes apparent that the feelings and emotions of the viewer can be influenced by a change in the lighting. The essence of lighting design is to solve the relationship between lighting, space, and people, to enable people to experience the most suitable lighting in a given space, and to appropriately address the functional needs of people. The most "Visceral " element in lighting is the human visual function; the lighting design should, therefore, also be designed to meet the most visceral needs of mankind, which is the pursuit of light.

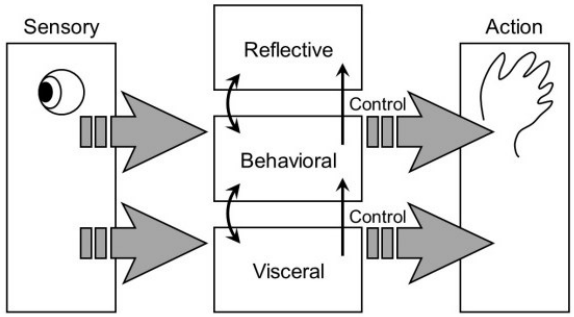

Fig. 5. Visceral, behavioral, and reflective analysis

From a cognitive point of view, emotional lighting requires us to analyze from the perspective of cognitive psychology: Visceral level (visual performance of lighting), behavioral level (intrinsic behavior of lighting design), and reflective level (the influence of lighting on people's thinking and emotions). The three levels of relationship are in chronological order; First the visceral layer is shown, then the behavioral layer, and, last but not least, the reflective layer.

B. Emotional Evolution Process

The three different dimensions of "visceral, behavioral, and reflective" are intertwined in any design. It is impossible for one of the dimensions to be absent. [10] The priority is to make these dimensions serve our emotions. Lighting designers should consider the three dimensions when designing a light environment and create a light environment that is beautiful, interesting, and easy to use. (**Fig. 5.**)

Experiments and other studies have proven that lighting has emotional effects on people. The psychological evaluation of a specific group of people is a complex process. The current technical means of evaluating a certain set of people is limited to objective experiments and subjective questionnaires. The objective experiments include human factors detection based on visual factors and brain waves based on the visual center.

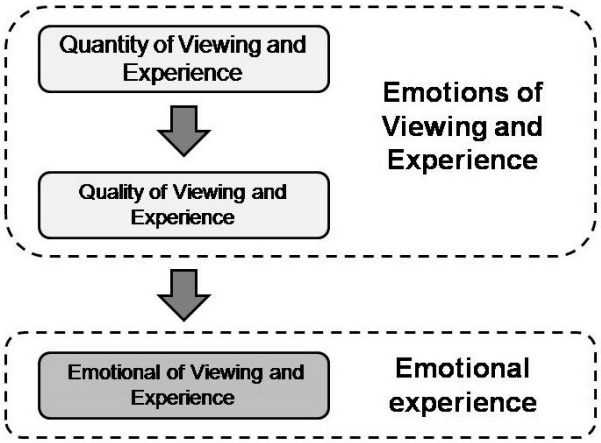

Fig. 6. Three-stage analysis diagram of sensory behavior

Appreciation of feelings is an important behavior in human social activities, which act on "lighting design" and involve the whole process of behavior. The viewer's feelings are divided into three basic stages: first, the quantity of feelings. People are looking for exhibits that they can view easily and clearly. Second, the stage of quality must be considered. People have begun to demand a certain quality of light in the environment space. In these two stages, the needs of the viewers remain at the most "basic" level, with the aim of obtaining more material-level performance in the exhibits. The third stage is that of emotional feeling. The focus of the viewer's attention turns to the emotional experience and cultural feeling of the exhibit. (**Fig. 6.**) This kind of perceptual viewing is a behavior that is based on the subjective emotional experience of the viewer. This perceptual viewing is connected to personal spiritual pleasure, psychological satisfaction, comfort, and superiority as its main feeling goals. It is important to attach more importance to the "emotional value" of the exhibits than to the "basic attributes" of the exhibits. Therefore, the essence of the perceptual viewing experience is also "emotional feeling". The motives of people's viewing extend beyond the basic conditions of the exhibit itself to include emotional motivations as well.

C. Emotional Lighting Design

Emotional feeling refers to a person's direct reaction to objective stimuli caused by human sensory organs, and the reactions are individual attributes of the stimuli produced in the human brain. Emotional feeling is the basis of all cognitive activities and the psychological basis of feelings. 80% of the information in the environment is obtained through vision,

such as the shape, color, and brightness of objects in a certain environment. Perception is the whole process of synthesizing stimuli on the basis of feeling and sensory attributes; it organizes and explains the attributes of sensory information, has integrity, selectivity, and understanding, and is a more active psychological activity.

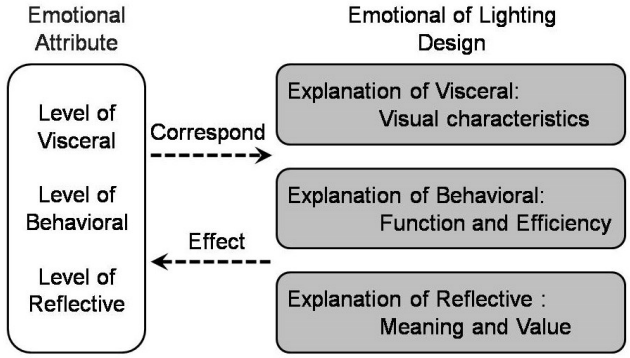

Fig. 7. Analytical Diagram of the effect of Lighting Design on the human emotional response

Imagination is the process of processing and transforming the existing images in the human brain and creating new ones, which are closely related to people's life experience, cultural accomplishments, and aesthetic taste. According to the mode of production, imagination can be divided into the creation and recreation of imagination. The former independently creates a new image, while the latter creates a new image based on a description in language or figure form. In the indoor environment, the color of the light, the method of lighting, and the shape of the light can stimulate the user's imagination. (**Fig. 7.**)

VI. CONCLUSION

This summary of a lighting design method based on creative thinking is intended to constitute an improvement on the theory and methods of lighting design. Lighting design is essentially a creative activity. Spatialization, visualization, and optical elements, which emotionally affect the characteristics of creation are the main characteristics of lighting design. Lighting design that is driven by creative thinking and innovative techniques is not limited to traditional functional design frameworks. Considering the elements of emotional lighting design, the use of the creative thinking method reflects the human-centered innovation lighting design method.

The light environment affects people's emotions in space. People's own emotions also affect their perception of the environment. Studies have shown that emotions can strengthen the specific intensity of external signals and affect people's sensitivity to external information. This research suggests that the design of the light environment can have a significant influence on the inner feelings of human beings. The internal relationship between the elements exhibited by a comfortable light environment corresponds to human emotional patterns. The research related to innovative lighting design methods, and the theory of spatialization, visualization and optical engineering are used to establish new theories and standards of emotional lighting design; through the use of the theory of explicit and tacit knowledge, they are also used to solve the design problem of the light environment, and most importantly, to influence the emotions of visitors.

REFERENCES

[1] Jennifer A. Veitch and Anca D. Galasiu, “The Physiological and Psychological Effects of Windows, Daylight, and View at Home,” NRC-IRC Research Report RR-325, 2012, pp.12-14.

[2] SusanFolkmanRichard S.Lazarus, “The relationship between coping and emotion: Implications for theory and research S Folkman,” RS Lazarus - Social science & medicine, 1988, pp.34-36.

[3] Toshihiko Yamakami, “Mobile social business ecosystems with revenue-generating emotional engineering: Lessons from mobile business in Japan [J]” Korea: IEEE DEST, 2011, pp.83-88.

[4] Jing Guo, Qin Su and Qian Zhang, “Individual Creativity during the Ideation Phase of Product Innovation: An Interactional Perspective,” John Wiley & Sons Ltd Volume 26, 2011, pp.31-48.

[5] Maher, Laura J. Mrs, "Aging-In-Place Home Modification: LED Lamp Color Temperature Preference Among Adults," Electronic Theses and Dissertations, 2017, pp.107-110.

[6] AJ Wilkins DPhil, "A physiological basis for visual discomfort: Application in lighting design," Lighting Res. Technol. Vol. 48, 2015, pp.44–54.

[7] WJM van Bommel, GJ van den Beld, WJM van Bommel, "Lighting for work: a review of visual and biological effects," Lighting Res. Technol. Vol. 36, 2004, pp.22–31.

[8] Z LIU, H CHEN, "Intelligent and Visualization Design of University Classroom Lighting Energy-saving Control System," Intelligent Computer and Applications. Vol. 6, 2014, pp.64–68.

[9] Timothy Onosahwo Iyendo, "Enhancing the Hospital Healing Environment through Art and Day-lighting for User’s Therapeutic Process," International Journal of Arts and Commerce. Vol. 3 No. 9, 2014, pp.101–119.

[10] DE KORT Y A W, SMOLDERS K, "Effects of dynamic lighting on office workers：First results of a field study with monthly alternating settings," Lighting Res. Technol. Vol. 42, 2014, pp.345—360 .