Applicable Prospects of Eye Tracking Technology in the Research of Landscape Visual Perception

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Abstract

This paper mainly adopts the literature research method, which analyzes the application progress and development overview of the eye tracking technology, as well as the technical features of the eye tracking devices. Combined with the research needs in landscape visual perception, eye tracking technology have application values in the following aspects: landscape attractiveness analysis, safety design of landscape environment, usability design of landscape facilities, landscape perception in motion, quality improvement of landscape information interface, cognitive analysis of physiological vulnerable groups and quality improvement of landscape education. Eye-tracking technology should be used reasonably in the study so as to exploit its advantages to the full and correct its deficiencies. The development of hardware technology and software technology of eye-tracking offers a new perspective and study platform for the study on landscape visual perception, which contributes to improving the scientificity of the study on landscape visual perception.

Keywords: Eye tracking technology, Visual perception, Landscape, Application

1. Introduction

Research related to visual perception has always been the hot issue of landscape studies, which is mainly manifested as the quality assessment of landscape aesthetics, the visual landscape assessment, and the impact of vision on designs [1-2]. Visual perception refers to the process that once the visual stimulation is received by the organ of eyeball, it is straightly transmitted to the brain for acceptance and recognition. Eye tracking technology has been widely used in the field of psychology research in recent years, since vision is one of the main factors that affect the psychological activities, and that more than 90% of the information that people acquire from the outside world comes from their eyes [3]. Psychologists believe that eye movement is the direct reaction of vision process, reflecting various human cognitive activities and influenced by multiple cognitive factors. Under certain visual stimulation, the eyeball movement has certain regularities and is closely related to cognitive activities like noticing, expecting, memorizing, reasoning, reading and so on. The visual perception is an important constituent part among "five senses" of human body. Studying it can promote the improvement in design quality of the perceived object, and eye tracking technology offers a scientific and technical platform for the research.

Japan applied the eye-tracking technology to the study on landscape visual perception relatively early. Some scholars studied the differences between Chinese and Japanese students in gazing at the regional landscape characteristics and the correlation between the river landscape characteristics and the gazing points of the viewer's [4]. eye tracking technology is also widely used in many design research fields such as the advertisement design, book design, web design, costume design, furniture design and costume design [5-7]. In fierce market, aspects like appearance, color matching, surface texture and availability have become the presupposition to attract consumers and then stimulate their purchasing desire to generate purchasing behavior. The multi-dimensional test as well as evaluation methods based on eye tracking technology have promoted the design quality of products.

At present, most of the research on landscape visual perception adopted methods of qualitative research and indirect evaluation. The subjectivity of research is relatively strong and the reliability of the results is relatively low. Along with the development of research, the methods of quantitative research and direct evaluation have gradually received attention. Eye tracking technology has advantages of quantitative study and direct evaluation. It can describe people's visual perception of the environment directly and quantitatively through accurately recording and analyzing their eye movements, and then it can provide decision-making bases for improving the quality of environment. Therefore, this technology has a broad application prospect in the research and reliability of results.

2. The General Situation of Development of the Eye Tracking Technology

The fast development of eye tracking technology benefited from the fast development of eye tracking devices. Methods of eye-tracking have experienced three phases of manual observation and recording, mechanical observation & recording and optical recording. In the end of 19th century, scholars recorded eye movement data by manual observation. This kind of study was only based on gazing time, blinking frequency and times, etc., so the results were often greatly affected by the environment. By the early 20th century, the mechanical observation recording was used in optokinetics. It was a recording method which connected the movements of eyes to the recording device through mechanical rotations. But this method was very complex, subjects' eyes needed to be narcotized, and the experimental results were still of comparatively low accuracy. Later, the optical recording method which used the light reflection principle of cornea and pupil was widely used in optokinetics. Along with the development of photographic technique, infrared technology as well as microelectronic technology and the enhancement of software development ability, the successful development of eye trackers provides advanced technology facility condition for the scientific research, making the precision, depth and width of the research have a qualitative leap, and pushing the development of visual perception scientific research. Eye tracker can capture the reflection of cornea and retina by infrared ray to record the user's eye movement track, gazing times, gazing time and other data. By processing the eve video information from the pupil camera, it can identify and determine the change of distance between the pupil center and the corneal reflection. By measuring the horizontal and vertical vector distance of these points, the coordinates of each fixation point can be obtained, and then an accurate measurement of eye movements can be acquired.

At present, several manufacturers in the world have developed eye tracking devices, and the high-accuracy eye tracker is the most common one. The structure of eye tracker generally includes four systems, namely the optical system, the pupil center coordinate extraction system, the vision and pupil coordinate superposition system and the recording and analysis system of images and data. According to carrying options, it can be divided into desktop eye tracker and portable eye tracker. desktop eye tracker needs to capture the static or dynamic scenery image information in advance according to the experimental design, which was completed by the subjects through tests in the laboratory; The subjects can completely and independently conduct normal activities after wearing the portable

eye tracker, so it is more suitable for the study on landscape visual perception in outdoor exercise condition (Figure.1).



Figure 1. TOBII Desktop Eye Tracker and Glasses-Type Eye Tracker

3. Application Directions and Methods of Eye Tracking Technology in the Research of Landscape Visual Perception

3.1. Application Directions of Eye Tracking Technology in the Research of Landscape Visual Perception

Currently, achievements of directly using eye tracking technology to develop the study on landscape visual perception is few, but its achievements in interior design, furniture design, costume design, web design, advertisement project, and illumination design are rich. Therefore, using these outcomes for reference in the landscape visual perception field can promote the development of relevant research on the landscape visual perception. eye tracking technology the research of visual perception in the following directions.

3.1.1. Landscape Attractiveness Analysis: Landscape environment should meet the needs of public taste, function, *etc*, so it's very important to know deeply its attraction to different kinds of groups. Through eye-tracking, data about the exciting point of landscape, aesthetic degrees of landscape, attraction of spatial form, attraction of spatial color and so on can be collected and analyzed. Combined with the investigation of public attitude and desire, a comprehensive evaluation of the landscape environment's attraction to the public can be obtained. Combining their own originalities, landscape designers can design landscape works which better meet public needs on the basis of this.

3.1.2. Safety Design of Landscape Environment: The security risks in landscape environment will form a threat to public lives and health. These security risks are mainly in such aspects as the water safety, power facilities safety, protection facilities safety, transportation safety, and light safety. By using the eye-tracking technology, public behavior characteristics such as attention, gazing points, selectivity and avoidance methods can be recorded and analyzed when safety problems occur. Thus, the safety level of design can be increased and a more comfortable and safe landscape for the public will be created. Taking "glare pollution" for example: with the improvement of living quality, landscape quality in the evening has become a major factor of measuring the comprehensive quality of landscape. However, the glare of landscape lighting has great

impact on the public. Eye-tracking technology can record people's sensitivity towards night glare so as to provide basis for scientific and reasonable illumination design.

3.1.3. Usability Design of Landscape Facilities: The usability proposed by cognitive psychologist, Gibson, refers to the properties which the products or environment can provide for users [8]. The definition of usability of ergonomic requirements of international standard [ISO9241/11] office visual display terminals (VDTs) is: usability refers to the effectiveness, efficiency and satisfaction degree of using certain products to achieve the specific objectives, in case of a particular user in a particular usage scenario [9]. Landscape facilities are the most commonly used landscape products, including leisure facilities, sanitary facilities, indicator signs, etc. Their usability has great influence on the comfort level of the public. Eye-tracking technology can find out people's selective behavior for different landscape facilities, so as to provide a scientific basis for the layout optimization and design of landscape facilities. Taking indication signs for example: the design of indication signs mainly consists of two parts which are pictures and words. They should have such characteristics as clearness, beauty, and full information expression so as to meet the needs of identifiability. Through eye-tracking can compare different signs' influences on public attention, comprehension and retention, and provide the basis for promoting the usability of signs design.

3.1.4. Landscape Perception in Motion: The public in landscape activities often acquires a series of continuous impressions from environment along with the movement, eventually forming the abstract understanding of environment and an overall understanding after induction [10]. Eye tracking technology should be used can research the access conditions of landscape spatial information in the process of human moving. For example, through analyzing visual angle, visual horizon, focus, focus time, *etc.* of human's eyes, we can understand human's attention to the scenery in their process of walking, crossing, driving and so on, and then have a deeper understanding of the sequence, derivative structures, *etc.* The change rule of public vision under different spatial attributes can provide the basis for promoting the optimization of space sequence and structure.

3.1.5. Quality Improvement of Landscape Information Interface

The interface of landscape information mainly refers to the Internet web pages associated with the landscape information release. With the development of landscape industry, it has been an important approach to release and receive information through the Internet. When users' channel cost to gain information from the network platform keeps decreasing, the presentation and design of information contents seem to be extremely important. Eye tracking technology should be used can analyze public visual browsing habits when they observe the interface of landscape information, master the influences of color, layout, information integrity, organizational element, *etc.* of web pages on browsers, and improve the efficiency and attraction of the interface of landscape information based on it, promoting the information benefits by optimizing users' experience.

3.1.6 Cognitive Analysis of Physiological Vulnerable Groups

Physiological vulnerable groups include old people, children, pregnant women, handicapped people, *etc.* [11]. Physiological vulnerable groups should have the equal right to use the landscape environment as normal people, which shows the social fairness and impartiality. The construction of landscape environment should consider the specific characteristics of the group in physiological and psychological needs. For example, due to the decreased visual ability, the cognitive ability of the old declines also, so the aged activity center should be adapted to this kind of change; Children are greatly different

from adults in concentration and cognitive level. Therefore, the design of children activity places should be more in line with children's characteristics. What's more, the landscape environment needs of special children like those with autism or hearing disorder must be paid attention to. Eye-tracking technology can analyze the characteristics in visual sensation of this type of people intuitively, providing basis for the place design.

3.1.7. Quality Improvement of Landscape Education: In recent years, the development in the subject and specialty of landscape architecture has been very rapid. As a burgeoning subject, it's very important to improve the education and teaching quality. Eye-tracking is the technology which can most directly analyze the concentration of students during lectures currently. Through the use of eye tracking devices, teachers are able to know students' observation content and time during lectures, and also analyze the relevant factors influencing the attention of students. Through eye-tracking research can provide the basis for improving the classroom layout, teaching materials, teaching methods, *etc*, so as to promote the improvement of teaching quality [12].

3.2. Application Methods of Eye Tracking Technology in the Research of Visual Perception

The experiment of eye-tracking generally includes the following three steps: experimental design, data acquisition and result analysis (Figure 2).

3.2.1. Experimental Design and Data Acquisition: The application of eye tracking technology must follow scientific methods for the rationality of experimental design will directly determine the reliability of the research results. It is first to determine the testing scene and subjects and record characteristics of the tested interior and outdoor environment. Interference of sound, light, *etc.* should be avoided in the testing scene. The selection of subjects should meet the requirements of research objectives; Then, it is to confirm the landscape vision identity factors and testing standards. Common measuring parameters are fixation counts, average staring time, fixation order, travelling trace of the fixation point in the horizontal level, average diameter of pupils, gazing ratio of each area of interest and so on [13]; Next, it is to implement tests and save the obtained data in computers or optical instruments; lastly, it is to use professional software to analyze the data and obtain results for the study.



Figure 2. Three Steps of the Experiment of Eye Tracking

3.2.2. Analysis of Experimental Results: There is a close link between the characteristics of eye movement and the information processing in the brain. Eye-tracking reflects the information processing procedure in human brains. The information provided by eye-tracking is not merely as simple as "how people see" and "what people see". The data acquired by the eye tracker can't be directly used. Data extraction and analysis should be conducted according to the research objective. Finally, statistical tables and visually statistical graphs will be formed. Currently, various manufacturers have developed analyzing software that matches the hardware. Using the software can analyze experimental results in an easy way. There are two common types of data processing software. One is the bundled software developed by eye tracker manufacturers which can conduct regular analysis of recorded data. The other one is the statistical software such as SPSS and SAS which can do data mining analysis and verify whether the results are of statistical significance.

4. Advantages and Disadvantages of the Application of Eye Tracking Technology in the Research of Landscape Visual Perception

4.1. Advantages of the Application of Eye Tracking Technology in the Research of Landscape Visual Perception

4.1.1. To Provide Precise and Reliable Data of High Quality: Research on landscape visual perception is mostly conducted by subjective evaluation methods, such as the scenic beauty estimation (SBE) method and the landscape comparison judgment (LCJ) method. These methods can reflect the landscape sense of subjects to some degree. However, the data mainly come from the subjective scoring of experts or the public, the scoring and assigning methods of which will affect the accuracy of the results. Eye tracker is a high-tech product based on modern infrared ray detection technology, and it can unprecedentedly reveal the intuitive sense and detailed experience in the users' subconsciousness. The microcosmic change process in subjects' psychology during the landscape experience could be revealed qualitatively and quantitatively at same time by the reappearance of "measuring index" on eye movement through the analytical tool with modern visualization, which is vital to improve the preciseness of research.

4.1.2. To Provide Intuitive and Visual Result Demonstration: The visualization frees people from observing and analyzing data information only through relational data tables. It also enables people to see the data and its structural relationship in a more intuitive way. The bundled software of the eye tracker can process data into dynamically visual graphs such as the fixation trajectory chart, heat map, cluster diagram and interest area which make the analysis more efficient. Furthermore, researchers can make the recorded data of eye trackers into visible figures, making the results look clear at a glance. For example, taking the heat map mostly used in eye tracking for example, the redder the regions in the graph are, the more focused these regions are, revealing the "heat" distribution in people's eyes.

4.2. The Application Disadvantages of Eye Tracking Technology in the Research of Landscape Visual Perception

4.2.1. The Complexity of Psychology Activities: People's behaviors are subject to psychological activities. However, people's psychological activities cannot be directly observed or measured, and can only be analyzed by the external performance. In reality, there is a divergence phenomenon about people's attention and fixation, which means that what people see does not necessarily represent what they think about. Only when people

are concentrated on a certain task, what they see and what they think are of a higher interrelation. And only then can the reliability of eye tracking study be accepted. In order to make research results more accurate, usually some auxiliary methods such as questionnaires and interviews will be adopted to validate the specific problems after eye-tracking tests.

4.2.2. The Complexity of Data Processing: One important principle in applied the eye-tracking technology is not to rely solely on the eye-tracking data. The data obtained from the experiment of eye-tracking can't be used directly. They need proper processing. For instance, can the time of gazing define what is good or bad? Provided that users are gazing for a long time, there are two possibilities: one is that they see something interesting, so they focus on gazing; the other one is that users are confused about some contents, so they have to spend time understanding them. Researchers need to combine multiple study methods to analyze the data of eye movements, and understand what the subjects are thinking about by inquiry or other methods.

5. Conclusion

In recent years, the eye tracking technology has been widely used in the field of psychology science, but it is hardly used in the field of the study on landscape visual perception. The development of eye-tracking hardware and software technology brings a new opportunity to the applied the eye-tracking technology, and provides a brand-new perspective and research platform for research. Therefore, as an advanced technological means, eye tracking technology can improve the level of science and technology in the study on landscape visual perception.

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