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Application Strategies of Eye-tracking Method in Nightscape Evaluation†

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야간경관 평가에서의 아이트래킹 분석 적용 연구

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ABSTRACT

There's a trend towards vitalization of nightscape planning businesses nationally and locally as well for city image making and activation of regional economy, but there is still no systematic nightscape planning going on for lack of relevant researches and objective evaluations. This study aims to suggest the guideline for nightscape planning by conducting an eye tracking experiment and survey for recognizing the characteristics of a nightscape. Furthermore, the authors intended to verify the eye-tracking method as a tool for landscape evaluation.

The research site was restricted in the campus of Virginia Tech, VA, and those were selected by experts' survey among various types of nightscape images. The variables for analyzing the characteristics of nightscape images selected were 'preference', 'safety(fear)' and 'clearness'. 'Fixation duration', 'saccade duration', 'scan path length', and 'pupil size' were selected as the eye movement measurements.

The results of this study are as follows: The first outcome found was that there were significant differences among the characteristics(preference, safety and clearness) of a nightscape by MANOVA, and these variables were correlated positively by Pearson's correlation. Secondly, there were differences on fixation duration, saccade duration and scan path depending on the nightscape setting statistically. Also, the eye tracking measurement in an open setting was recorded lower than enclosed settings. In the result of a heat map, we found the meaning of the fixated areas on both viewing without intention and viewing intentionally. It turned out that the fixated areas were consistent with the areas the subjects felt preferred and clarity in all of the nightscape images, which means people usually focus on what they prefer and see clearly in a certain nightscape.

Based on this result and previous studies, the authors could make a conclusion that eye tracking method can apply to evaluate nightscape settings in terms of analyzing the whole characteristics and finding specific points for the detailed analysis as well. Therefore, these results can contribute by suggesting nightscape planning, implication of the landscape evaluation, and implication of the eye tracking study.

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Key Words: Visual Perception Attention, Nightscape Planning, Landscape Preference, Landscape Evaluation

국문초록

도시이미지 형성 및 지역 경제 활성화를 위해 국가 및 지자체별 야간경관계획 사업이 활발하게 추진되는 추세이지만, 현재까지 야간경관 관련 연구 부족 및 객관적인 평가 방법의 부재로 체계적인 야간경관계획이 이루어지지 않고 있다. 이에 본 연구에서는 피조사자들의 눈의 움직임 평가 및 설문조사를 통해 야간경관 특성을 분석하여, 향후 바람직한 야간경관계획에 시사점을 제공하고자 한다. 나아가 아이트래킹 기법(Eye-tracking method)이 경관 평가에 있어 객관적인 평가 방법이 될 수 있는지 검증하고자 하였다. 연구 대상지는 미국 버지니아 공과주립대 캠퍼스이며, 다양한 야간경관 이미지 중 전문가 평가를 통해 대표 야간경관을 선정하였다. 선정된 야간경관 이미지의 특성을 분석하기 위하여 사용된 변수는 선호도, 안전함(두려움), 선명도이며, 눈의 움직임 분석을 위한 변수는 고정 지속시간(fixation duration), 순간적 움직임 지속시간(saccade duration), 주사경로 길이(scan path length), 동공 크기(pupil size)이다.

분석 결과는 다음과 같다. 첫째, 다변량 분산분석(MANOVA)을 통하여 야간경관의 유형에 따라 선호도, 선명도, 안전함(두려움)의 차이가 통계적으로 유의하였으며, 상관관계 분석을 통해 선호도, 안전함, 선명도 사이에 정적인 영향관계가 있음을 도출하였다. 둘째, 야간경관의 유형에 따라 눈의 움직임 변수들(고정 지속시간, 지속시간, 주사경로 길이) 차이가 유의함을 파악하였으며, 상대적으로 오픈된 경관이 폐쇄된 경관보다 눈의 움직임 변수 수치가 낮은 것으로 조사되었다. 셋째, 눈 움직임 강도 지도(Heat map) 비교 분석에서는 피조사자들이 무의식적으로 응시한 강도 지도 결과와 선호되는 구역 및 선명하게 보이는 구역 응시를 지시했던 강도 지도 결과가 유사하게 나타나는 결과를 확인하였다. 이는 사람들이 무의식적으로 야간경관을 응시할 때, 다른 구역에 비하여 주로 선호하고, 선명하게 보이는 구역을 강하게 응시한다는 것을 의미한다.

종합해볼 때, 본 연구에서는 야간경관의 유형에 따라 전체적인 선호도, 선명도, 안전함(두려움) 등의 지각하는 특성 및 눈의 움직임 차이를 검증할 수 있었으며, 나아가 야간경관 구역별 강하게 응시하는 구역과 해당 구역이 의미하는 특성을 파악할 수 있었다. 본 연구 결과는 경관 평가에 있어 아이트래킹 기법 적용하여 환경별 유의미한 차이를 입증했다는 데에 의미하는 바가 크며, 향후 경관 평가에 시사점 제시 및 야간경관의 이용 만족도 향상을 위한 야간경관계획 시 전략적으로 참고할 수 있을 것이다.

주제어: 시지각 주목도, 야간경관계획, 경관선호, 경관평가

Ⅰ. Introduction

People's increasing demands for higher environmental landscape quality have promoted rapid development in the construction of urban lighting landscape(Xiaofei *et al.*, 2010). Even though, the significance of nightscape planning has been discussed by many previous studies focusing on specific targets such as streetscape(Painter, 1996; Choi *et al.*, 2006; Bullough and Bullough, 2013), monument(Tural and Yener, 2006), there have not been enough studies dealing with nightscape alone. Designing for a nighttime lighting landscape is a task of great significance because it is closely associated with fear and human behavior. According to Painter(1996), the types of crime which mostly cause anxiety are focused in urban areas especially after dark. Fisher and Nasar(1992) also pointed out the consideration of a nighttime design for reducing fear through investing the relationship between fear and exterior settings. For human behaviors at nighttime, Ngesan *et al.*(2012) stated it is necessary to consider a night design that will increase social behavior and activities in the evening. This is because the use of public spaces at nighttime is based on satisfaction and preference towards a nightscape. Ahn *et al.*(2007) also suggested that the interest for nightscapes has been increasing for commercial and cultural effect by utilizing this as a tourist attraction. Above studies explain that nightscape planning is necessary to reduce fear and to enhance satisfaction of usage at nighttime. However, urban environment is still dominated by darkness and urban lighting design plans have been implemented without coordination and have mainly used the designers' intuitive creation(Choi *et al.*, 2006). Most of studies

regarding landscape planning for daytime have usually conducted quantitative methods for many years through investigating landscape preferences(Larsen and Harlan, 2006; Barroso *et al.*, 2012 Howley *et al.*, 2012). As aforementioned, lack of quantitative approach on nightscape planning is becoming a growing issue.

In this study, the authors tried a new design methodology for nightscape planning using eye tracker, which is used to investigate people's eye movement related directly with people's recognition of their environment. Eye movements are used to measure the attention when viewing a scene; therefore, it is hypothesized that different types of attention engaged should be reflected in the eye movements(Berto *et al.*, 2008). Most of the previous studies on eye movement have used an eye tracker to find out what people are interested in the field of HCI, marketing and so on in particular. However there were not enough studies using eye trackers in the field of space such as landscape architecture, architecture, and urban planning. Using eye trackers on landscape evaluation could be an objective tool in order to investigate the attention areas that people are interested in. According to Berto *et al.*(2008), these are two primary forms of attention: one is based on interest, the other is on the effort of using the eye tracking method. But there have been no studies dealing with the areas where people are focusing on. It is necessary to find out what the people's focused on using eye tracker in landscape evaluation including suggesting desirable nightscape planning as well. Especially, a nightscape evaluation is needed to involve many variables such as light, shadows from some elements, and so on compared to the landscape evaluation in daytime. That means the more detailed analysis focusing on visual attention is required in nightscape evaluation beyond previous landscape evaluation methods such as the survey based mainly on participants' subjective feeling. Therefore, the objectives of this study were to explore people's eye movement towards different type of nightscapes in order to suggest desirable nightscape planning and verify the eye tracker in the landscape evaluation as well.

Ⅱ. Methodology

This study is conducted focusing on nightscape. The study verifies the following three main assumptions for the possibility of eye tracking method on landscape evaluation.

Assumption 1: Physical setting and elements in nightscape will affect people's level of preference, safety(fear), and clearness.

Assumption 2: Eye movements will vary depending on the different nightscape settings(physical setting and elements in nightscape).

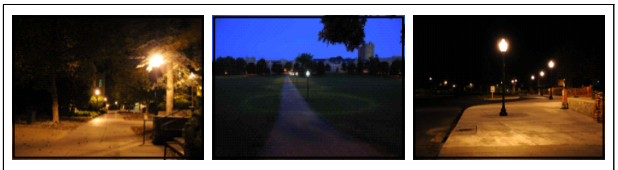
Assumption 3: Where people's focus is fixated that is related with preference, safety(fear), and clearness.

1. Design(Survey Instrument)

In order to verify these assumptions, a survey instrument containing three digital photographs(Refer to Figure 1) was conducted. Before describing the survey instruments, setting up what nightscape means is very critical. Nightscape is a mixed word using of night, and scape which means originated by shape. Oh(2004) described that nightscape further has the meaning of intention or direction using an artificial light. Because of this, people use lightscape instead of nightscape recently. In this study, we took some nightscape photographs following its meaning which is 'the scenes with artificial lights after dark, around 7 to 8 pm.'

These three photographs were chosen as typical settings in Virginia Tech campus among thirty photographs taken by 3 landscape architect faculties. The first photo depicted an enclosed setting surrounded by trees, which is the most common scene in this campus. The second was the open environment showing the path and the fields in front. The third image depicted a curved path setting surrounded by buildings.

As the artificial light could affect a lot on nightscape evaluation, we considered the intensity and intervals of the street lights. The intensity of the light in this campus is totally the same, and we restricted the settings and the intervals of the street lights to be the same. Additionally, to avoid the effects of transparency by vegetation, all photos were taken in the same season and at the same time on the Virginia Tech campus in Blacksburg, Virginia.



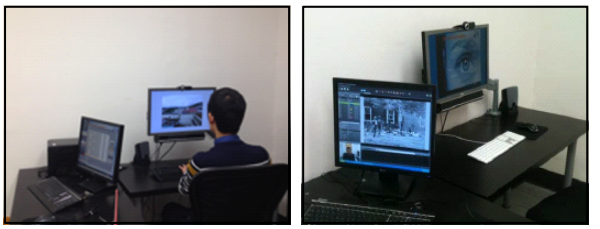
a: E1 b: O1 c: P1

Figure 1. Survey instrument

2. Eye Tracking Apparatus

This study used a video-based, pupil/corneal reflection eye tracking apparatus that included an infrared eye movement camera and recording system(Red 250) manufactured by SensoMotoric Instruments(SMI) of Germany(Refer to Figure 2). The infrared sensor was positioned directly below the monitor. As participants viewed a photograph on the monitor, the eye-tracking apparatus tracked and recorded points of gaze(or areas of interest; AOIs), length of gaze, and saccades(eye movements between focused gazes on AOIs). The system used Begaze2 software that is part of the Eye-Tracking system by SMI to record and analyze the collected data.

The research was conducted at the School of Visual Arts Perception and Usability Testing Laboratory at Virginia Tech in Blacksburg, Virginia. While the survey was conducted, only the investigator and research participant were present in the lab to minimize distractions for participants.



a: Experiment environment b: Experiment environment

Figure 2. Eye-tracking equipment in the Perception and Usability Testing Laboratory at Virginia Tech. An operator controls the foreground computer, and a subject sits in front of the screen in the back.

3. Participants

A total of 26 participants with age ranging from 20 to 40 years, were recruited at Virginia Tech. 26 samples for this study could be comparably lower than other quantitative studies, but Kim(2006) stated that 5 to 10 subjects in eye tracking analysis would be general, since this analysis costs a large expenditure of money and no further high level analysis is needed. The participants are of various nationalities such as Korean, American, European, Indian, and Malaysian. The proportion of Asians to Westerners among the participants was 6 to 4. The authors informed the participants for their right to withdraw themselves. For the reliability of this study, pre-experiment which was conducted by 3 participants was carried out with the same steps during the main experiment. At last, 23 valid samples were produced after eliminating two men and one woman due to irregularities. All participants were students or researchers in Virginia Tech.

4. Measurement

The measurement of this study could be divided into two parts; one is to investigate characteristics of nightscape, which was supposed to compare eye movement for the further step in this study. The other is about the eye movement measurement to analyze subjects' eye movement. For selecting evaluation variables of nightscape in this study, two steps were proceeded; one is from reviewing previous studies that dealt with variables for evaluating nightscape, the other is from expert survey. Previous studies on nightscape have used 'Preference'(Ahn *et al.*, 2007; Lee *et al.*, 2009; Nikunen and Korpela, 2012), 'Safety (fear)'(Painter, 1996; Lee *et al.*, 2009; Knight, 2010; Nikunen and Korpela, 2012), 'Clearness'(Ahn *et al.*, 2007), 'Magnificence' (Lee *et al.*, 2009), 'Warmth'(Lee *et al.*, 2009), 'Dynamics' (Lee *et al.*, 2009)' and so on as an overarching variable for evaluating or describing each nightscape. Based on the variables from previous above studies, expert survey was conducted regarding which variables could be appropriate to evaluate the nightscapes by 10 experts who are faculties or researchers in the field of landscape architecture, architecture, and city planning. Three variables(preference, safety, and clearness), lastly, were selected as a variable for evaluating characteristics of each nightscape image in this study according to majority of experts.

To analyze participant's eye movements for each image, the investigator examined the eye-movement data for fixation duration, saccade duration, scan path length, pupil size, and heat map(Refer to Table 1 for a summary of terms used in the paper). Total duration of gaze measured the total time for participants' viewing each image. Fixation reflects the primary distribution of attention(Berto *et al.*, 2008). That is, longer fixation reflects to more attention than lower fixation relatively. Like this, fixation duration has been known as a representative eye movement measurement when we experiment eye movement generally and previous studies on eye movements have used fixation duration for experimenting eye movement on their studies(Lee *et al.*, 2005; Underwood *et al.*, 2008; Massaro *et al.*, 2012). Saccade duration stands for that total time of

eye movements as the gaze travels from one point of fixation to another. It has been widely used(Kotval and Goldberg, 1998; Alvarez *et al.*, 2010) like fixation has been done as an eye movement measurement. Besides, the other eye movement measurements, scan path length(Lanyon and Denham, 2004; Unema *et al.*, 2005; Kato and Konishi, 2013) and pupil size (Conati and Merten, 2007), and heat map(Massaro *et al.*, 2012) in eye movement studies have been used for explaining eye movements. Scan path length means the total length of gaze positions. Therefore, we could assume that relatively longer scan path lengths are from longer time or longer paths from one to another points in one frame. At last, heat map shows gaze positions plotted on the fixated areas, with red being the areas of the longest fixation. It could help us to grasp what exact areas are focused easily from the plotted spots and colors.

Above previous studies would be the foundation why this present study chose those four eye movement measurements (fixation duration, saccade duration, scan path length, pupil size) and heat map in order to explore the specific areas in which subject focused for analyzing nightscape.

Rather than analyzing every second of each image, the author focused on the first three seconds when analyzing eye movement measurement of each image based on Byrne *et al.*(1999). That study highlighted first fixation is meaningful for describing subjects' interested area.

To analyze preference, safety(fear), clearness rating and eye movement differences, an analysis of variance(ANOVA), multivariate analysis of variance(MANOVA) were performed for the three different images. In addition, Pearson's correlation was run to find out correlations between preference, fear, and clearness before running multivariate analysis of variance (MANOVA).

Table 1. Summary of terms used in the paper

Terms	Description
Fixation duration	Total time of all fixated area (no movement)
Saccade duration	Total time of eye movements as the gaze travels from one point of fixation to another
Scan path length	The total length of gaze positions and eye movement plotted on the stimulus image
Pupil size	Average size of a pupil
Heat map	Gaze positions plotted on the fixated areas

*Definitions follow SMI(2012)

5. Procedure

The 26 participants were instructed about the purpose of the study and the experimental procedure before conducting experiment.

The experiment was conducted in the room at the School of Visual Arts Perception and Usability Testing Laboratory at Virginia Tech in Blacksburg, Virginia, consisted of individual session lasting approximately 30 min. Before starting the experiment, participants underwent an eye-tracker calibration phase by letting them follow a red circle on the monitor. Preparing for experiment, participants were positioned in front of a monitor and infrared camera installed at the bottom of the monitor.

Participants were shown three digital photographs(three types of nightscape taken in Virginia Tech; Refer to Figure 1. Survey Instrument). Even though we had three different types of images, total images that participants watched were 9 photographs in order to consider reliability of this study and make sure what the areas participants closely watched mean for. Images appeared one at a time on the monitor. This experiment was divided into two steps. In the first step, the investigator let participant watch each image on the monitor one by one. Moreover, they were asked to rate their level of preference, safety(fear), and clearness on a 7-point Likert-type scale(1 is very unpleasing, very fearful, and very unclear and 7 is very pleasing, very safe, and very clear). The other step was that participants watched the very preferred, very fearful, and very clear what they thought following a investigator's direction. Participants were allowed to watch each image for as long as they wanted before pressing the spacebar to rate their rating of preference, safety(fear), and clearness. Once participants rated that score, the monitor advanced to the next image automatically. The investigator watched closely the video monitor for checking eye tracker was going well during the each experiment.

After viewing each image and rating the level of preference, safety(fear), and clearness for each image, participants filled out the questionnaires consisted of demographics such as gender, age and major. To make similar environment what the nightscape is like, all lights in the room were turned off.

Ⅲ. Results

1. The Results of Survey

Subjects' perception of preference, safety(fear), and clearness how highly they rate each nightscape images are presented in Table 2 and Figure 3. In a preference result, the mean ratings ranged from 4.09(curved path) to 5.17(open setting) on the 7 point scale. The gab of mean ratings was not that high one another, but subjects preferred open setting image rather than the other things. On the other hand, the nightscape with the lowest preference was the nightscape with curved path setting. As there were correlations significantly among preference, safety(fear), and clearness using Pearson's correlation(Refer to Table 3), the authors tested Multivariate analysis of variance(MANOVA) for examining if the difference between the mean of scores of each different nightscape were statistically significant. Before looking into the results of MANOVA, the authors could find out there were strong positive relationship (Pearson's r=0.880, p<0.01) between preference and clearness on nightscape, and strong positive relationship(Pearson's r= 0.883, p<0.01) between safety(fear) and clearness additionally. There was positive relationship(Pearson's r=0.473, p<0.05) between preference and safety(fear) besides. Thus, it could be described the preference is in inverse proportion to fear and in proportion to clearness strongly on nightscape. The result of MANOVA showed the difference was significant on the preference rating(F=4.646, p<0.05). In a post hoc test (using Tukey), nightscape with curved path was different with two the other settings(Enclosed nightscape setting and open nightscape setting). Safety(fear) was resulted in that open nightscape setting was the highest score. Along with the results of preference, the difference of fear on each different setting was significant(F=14.346, p<0.01). Additional

Table 2. Participants' mean preference, safety(fear) and clearness rating for each image

		E1	O1	P1
Preference	Mean	5.13	5.17	4.09
	STDEV	1.60	1.27	1.20
Safety(fear)	Mean	5.43	6.17	4.57
	STDEV	1.08	1.03	0.95
Clearness	Mean	5.74	6.00	5.22
	STDEV	1.01	1.24	1.00

Subjects reported their level of preference, fear and clearness in response to each image on a 7-point Likert-type scale where 1 = very unpleasing and 7 = very pleasing.

Table 3. The result of correlation analysis

		Preference	Safety(Fear)	Clearness
Preference	Pearson's r	1	.473*	.880**
	Significance		.023	.000
	N	23	23	23
Fear	Pearson's r	.473*	1	.835**
	Significance	.023		
	N	23	23	23
Clearness	Pearson's r	.880**	.835**	1
	Significance	.000		
	N	23	23	23

*p<0.05, **p<0.00

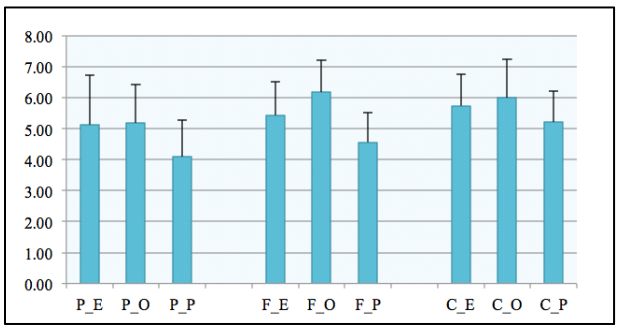


Figure 3. The result of preference, fear, and clearness

Tukey test proved those three settings were totally different one another. For the result of clearness through MANOVA, the difference was significant statistically(F=3.477, p<0.05).

2. Eye Movement

The eye tracking results for the three different settings were summarized in Table 4 and Figure 4. For the fixation duration, P1(Curved path setting) was the highest score (4,648.86). As expected, significantly longer fixation durations showed in the P1 that was the least preferred image. The fixation duration of E1 showed second highest one(3,134.17), and then O1 was the lowest one among three settings. Using ANOVA the authors examined if the difference between the mean variables of eye movement depending on different setting were statistically significant. The results of four eye movement measurements(fixation duration, saccade duration, scan path length, and pupil size) of eye movement through ANOVA were not always significant. The difference on fixation duration was statistically significant(F=3.369, p=0.040). In a scan path length, P1 also indicated the highest number(3,422.48)

and O1 was the lowest one(1976.52) among them. The author could find the difference of three setting on scan path length significantly through ANOVA(F=3.335, p=0.042). The results of saccade duration showed that P1 was the highest one (887.58). Even though the difference of saccade duration mean on different setting seemed significant one another, the result of ANOVA indicated this difference fails to achieve statistical significance(F=0.429, p=0.653). The result of pupil sizes on different settings indicated E1 was the highest setting (15.67) among them. But, the differences of pupil size on different settings were not significant statistically(F=2.958, p=0.059).

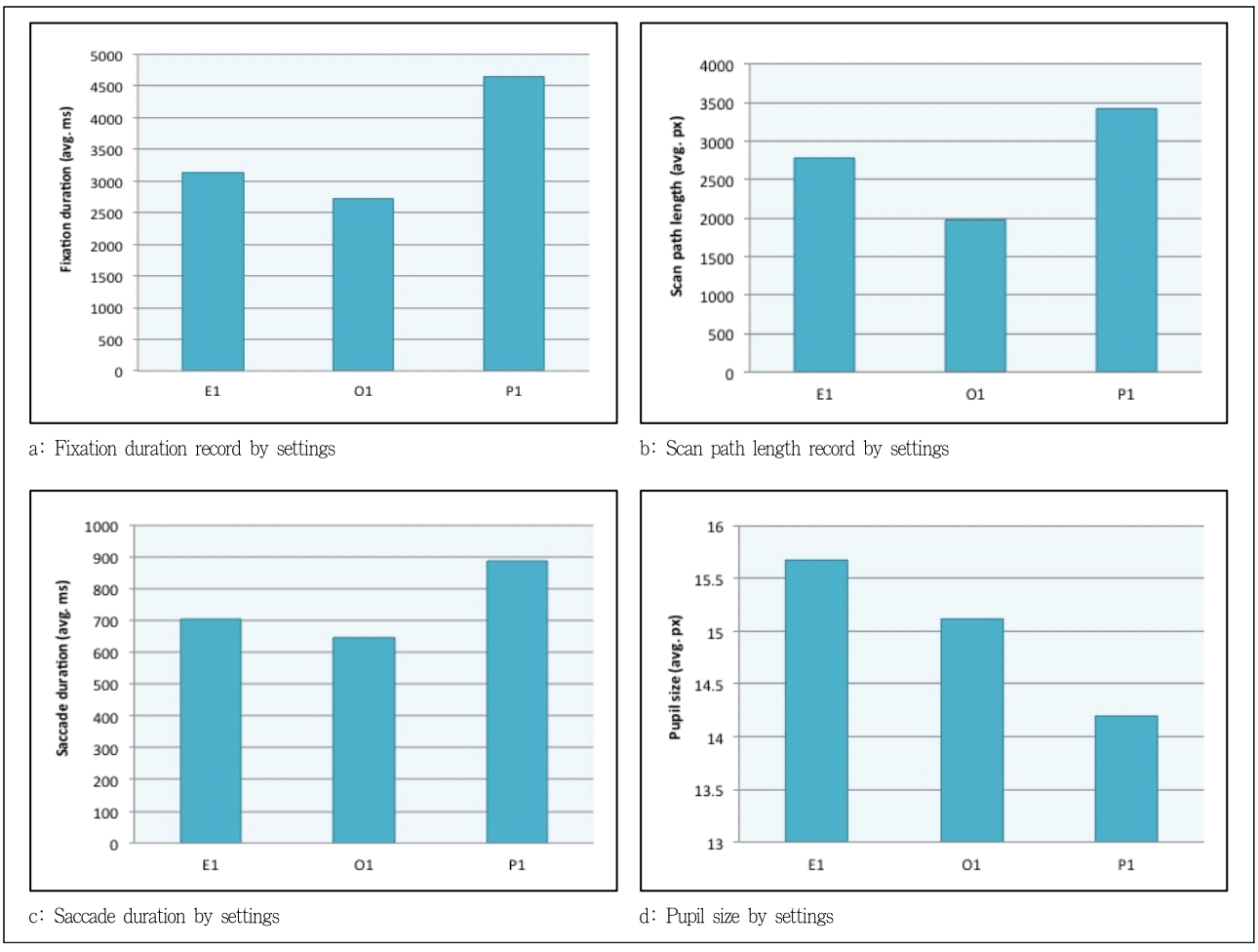
Table 4. Results of eye movement analysis for each image

Settings	Fixation duration (avg. ms)	Scanpath length (avg. px)	Saccade duration (avg. ms)	Pupil size (avg. px)
E1	3,134.17	2,776.30	703.90	15.67
O1	2,727.20	1,976.52	647.70	15.12
P1	4,648.86	3,422.48	887.58	14.19

3. The Areas Subjects Focused on

Even though studies about eye movement conducted those studies based on the thinking that what people focused on corresponds to what they are interested, there were no studies to investigate the reason why the subjects focused on certain areas. With this critical mind, the authors experimented what the areas subjects focused on means through comparing 4 different heat map images each different setting. The results of the experiment were drawn into heat map(Refer to Table 5).

The first column on Table 5 is the area subjects looked at without intention. The subjects looked at the first column image freely while their eye movements were recorded. From second column to fourth column, the researcher gave a direction for watching the images to each subject. In a second



a: Fixation duration record by settings

b: Scan path length record by settings

c: Saccade duration by settings

d: Pupil size by settings

Figure 4. The result of eye movement in each image

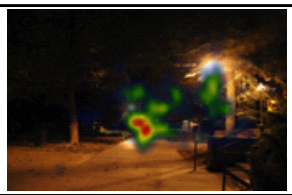
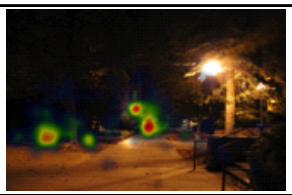
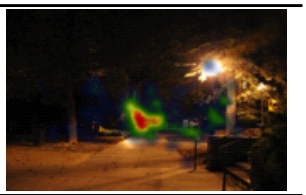
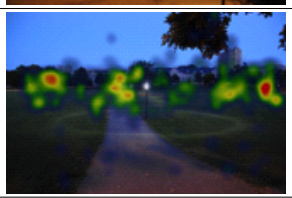
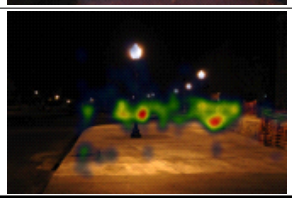
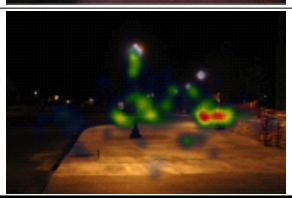
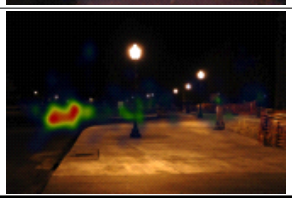
column image, the researcher let subjects see the most preferred area in their own mind. Third column indicates the area what the most fearful areas of the subjects. Fourth one was the most clear areas what the subject thought.

For the enclosed nightscape setting, it showed that the image without intention was similar to the preferred area what subjects thought basically in a heat map(Refer to Table 4). The subjects focused on the center area of this image and the bottom area of right light intensively in both first and second column images. Both the center of this image and the left darkest part was the most fixated area in the fearful area of subjects. The authors could grasp the areas the subject was fixated depend on subjects' intention. In case of open nightscape setting, the heat map image fixated without subjects' intention indicated subjects' foci were fixated the center of the image at the end of the path. The result of heat map without subjects' intention had similar pattern with the heat map of second column, which researcher let subject focus on the preferred area. The heat map of the clear areas of subjects located at four columns also made the most fixated area on the center of that image, along with previous result. It was the same pattern with the result of heat map in enclosed nightscape setting. On the contrary of previous things, the authors found that the fearful areas of subjects were scattered at the end line of the lawn. The subject seemed to focus on the areas trees were densely among the fixated areas. The nightscape with curved path indicated subjects' foci were fixated on the center of that image, the right areas and the peripheral of those on the heat map without subjects' intention. Compared to the preferred areas on subjects' thought, those patterns were similar to each other. Especially, subjects also focused on the right bottom side of center light on their preferred areas. The heat map of the fearful areas on subjects' thought indicated to be fixated strongly on left areas, which is considered the darkest areas. In the clear areas on subjects thought, subjects tended to focus on the center, right areas, and the left areas of that image.

Ⅳ. Discussion

The three aims of this study were to explore the differences of characteristics on nightscape[preference, safety(fear), and clearness] depending on the different physical settings and elements; to prove the differences of eye movements across the different physical settings and elements as well to determine what people's foci were fixated means. It was verified that the differences of characteristics on nightscape were significant through MANOVA test. In addition the authors could recognize that there were strong correlations among the characteristics before conducting MANOVA. It implies that the how people feel feared and how clear people look at it could affect the level of preference on nightscape. Thus, we

Table 5. The fixated areas in each image

	The area subjects looked at without intention	The preferred areas on subjects' thought	The fearful areas on subjects' thought	The clear areas on subjects' thought
E1				
O1				
P1				

have to make nightscape elements fearless or less terrifying and make the elements look clear by situating the light close to the nightscape elements in order to improve the preferences of nightscape. The setting with the highest preference, safety (fear), and clearness was O1, which is the open nightscape setting. In contrast, the lowest one on preference, safety(fear), and clearness was P1, which is the nightscape with curved path setting. Interestingly, O1 that was the highest on preference, safety(fear), and clearness had the lowest number on most of eye movement measurements(fixation duration, saccade duration and scan path length). It implies that there is a correlation negatively among landscape characteristics[preference, safety(fear), and clearness] and eye movement measurements in a way. This result is consistent with Fitts *et al.*(1950) and Just and Carpenter(1976)'s study, which resulted in that a longer fixation duration indicates difficulty in extracting information, or it means that the object is more engaging. While viewing each image on this research, subject might stay longer to understand better on some images and then it led those images to be less preferred, safe, and clear like P1's result. Berto *et al.*(2008)'s results are also relevant to this research and support the above result on this research. They compared eye movements(fixations and saccades) on between high on fascination and low on fascination in order to verify Kaplan's description of "soft fascination." The results of that study stated that differences in eye movements suggest that less effort is required to view high fascination scene than low one. If we regard high scored images on preference, safety, and clearness of this research as high fascination scenes on the result of above study, that study supports this research enough. There is another previous study(Goldberg and Kotval, 1999) that supports our research, which suggested a longer scanpath indicates less efficient searching and it might come from a sub-optimal layout. The lowest scored image(P1) in any characteristics indicated the longest scan path. Therefore, the authors could imagine the reason that the P1 was the lowest comes from that P1 was less efficient setting in a way even though other variable can also have a decisive effect on that. This result also can be the implication for desirable setting or element on certain place or space. Contrary to previous studies that support this research, Lee *et al.*(2005) found that there was a positive relationship between eye movements and color preferences. It would be expected that eye movements vary depending on which object or environment. To sum them up, the authors can derive the conclusion that the eye movement(fixation duration, saccade duration, and scan path length) is in inversely proportional to preferences, safety, and clearness on nightscape. However, there was no significant results in the pupil size even though Conati and Merten(2007) stated the pupil size has been shown to have a positive correlation with cognitive load.

The most likely the outcome of this research is to explore what the areas the subjects focused on meant exactly. Even though previous studies(Fitts *et al.*, 1950; Alexander, 2006) have stated what people see is related to what the preferred areas are, there were no study that can verify that security and clearness could affect the areas where people focus on. The result of the studies about what made people focus on certain areas supports the above assertion. In our research, the subject focused on without intention was consistent with roughly the areas the subject preferred and looked clear and not for the most fearful areas. This result is needed for comparison with the previous outcome that the most preferred, safe, and clear image got the less eye movement measurements (fixation duration, saccade duration, and scan path length) among three different nightscape settings. The authors made a suggestion that eye movements(fixation duration, saccade duration, and scan path length) are inversely related to the preferences, safety, and clearness of a nightscape when it comes to the whole image. Quite the contrary to it, we could make the conclusion that people focus on the areas where they prefer when it comes to specific areas of one image through comparing the above two outcomes in this study. Previous studies(Alexander, 2006) show an eye movement supports these studies in terms of that people's foci are fixated more on the areas of interest. However there was a study(Friedman and Liebelt, 1981) contrary to this study, which concluded that a fixation on incongruous objects is longer than fixations on other objects.

Besides, we need to focus on the outcome that subjects' fixated areas were consistent with not only preferred areas but also clear areas. Through this, the authors could claim that people focus not only feeling' preferences but also feelings' cleared on certain areas intensively. This result enables us to investigate furthermore studies based on what areas people would focus more based on what they feel prefer and clear. The subjects focused on exactly also make a contribution on designing nightscape in this study.

V. Conclusion

The background of this study came from the thoughts that have not been studied to explore eye movement on landscape evaluation using eye tracker and more precise experiments are needed for specific nightscape planning in particular. Therefore, this study investigated the eye movement measurements and the eye movement patterns comparing the characteristics of each nightscape image. Eye tracking offers more than just a research tool(Gog *et al.*, 2009) and can figure out what people focus on, which is relevant to the preferred areas as well through it. With these backgrounds, this study was intended to explore the differences on nightscape[preference, safety(fear), and clearness] across the three different nightscape setting. In addition, the authors tried to figure out the difference of eye movement depending on nightscape setting statistically and to determine where people's foci were fixated meant.

To accomplish this, the authors were determined the appropriate variables not only for evaluating nightscape, but also comparing eye movement measurements(fixation duration, saccade duration, scan path length, and pupil size) for verifying eye tracking method as a tool of landscape evaluation. The experiments for three different nightscape settings were conducted using eye tracker and survey for evaluating preference, safety(fear), and clearness were carried out together.

The meaningful outcome could be divided into two parts. The first outcome was that there was a correlation between the characteristics[preference, safety(fear), and clearness] of nightscape images and eye movement measurements(except for pupil size) negatively. This result was consistent with previous studies on eye movement(Fitts *et al.*, 1950; Just and Carpenter, 1976; Goldberg and Kotval, 1999; Berto *et al.*, 2008). From this result, we can use eye tracking method to evaluate the whole characteristics of certain settings. Assuming the evaluations on nightscape could be subjective to some degree, additional survey for evaluating the whole characteristics of settings would be needed for the detailed analysis. In our result, we could judge that people would prefer the open settings(O1) to two enclosed settings(P1, E1) on nightscape evaluation. Therefore, it is desirable to make nightscape settings open in the overall settings of nightscape.

For the detailed planning implications of nightscape, we could suggest from second meaningful result. The second result we found was the meaning of the fixated areas both viewing without intention and viewing intentionally. It turned out that the fixated areas were consistent with the areas subject felt preferred and clears all of the nightscape images. For the nightscape evaluation, the total level of preference, safety(fear), and clearness would be contrary to eye movement measurement(for fixation duration, saccade duration, and scan path length). These results might come from the effortful objects or less efficient setting of nightscape setting that was recorded low on eye movement measurement.

Based on this result and previous studies, the authors could assert the fixated areas which mean the preferred areas and clear areas on people's thought partially. Therefore, these results can also contribute not only for the eye tracking study but also for the implication for the nightscape study. Since the fixated areas were influenced by how clear the image was, making nightscape clearly by situating the light close to the nightscape elements could be one of the critical factors for the desirable nightscape planning. We also should make the nightscape elements fearless or less terrifiying by not making the spaces dark or enclosed areas surrounded by many elements or trees from the results of inverse correlations between preference and fear on nightscape.

In addition, both eye movements were different significantly depending on nightscape setting and the fixated areas were consistent with the most preferred and clear areas proved eye tracking methods as a tool for evaluating nightscape and further studies related with landscape.

Although, this study describes the initial evidence that eye movements are different depending on different settings and what makes people focus on certain areas, there are certain limitations on this study. The first limitation was that there were no enough nightscape settings even though the authors used the representative setting for nightscape in campus effectively. The second limitation was lack of implication for nightscape planning. This study is an exploratory study that does not suggest completely how the nightscape planning supposed to be done. At last, there could be some errors on the part of the participants who are accustomed to the campus environment in this study. We could not determine the variables from the familiarity of each location.

Even though there might be brought up the limitations like above, this study made a contribution in terms of the possibility of eye tracking method on landscape evaluation and implication for nightscape designing.

Future research is required to identify area or object, which would be more fixated with comparing similar setting for the specific design guideline based on this study. Additionally, we will consider the validity and reliability of eye tracking method for more desirable study.

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