Difference of Perceived Fear between Actual Environment and Image-based Environment Using Eye Tracking Method

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1 Introduction

As outdoor nighttime activities increase, so too has demand for quality nightscape design. However, designers to date have focused their attention mainly on how people use designed spaces during the daytime, without considering people's uses and behaviors at night. Nevertheless, some previous studies (e.g., GUO et al. 2011; NGESAN & KARIM 2012) have recognized the importance of designing for nighttime users, including the potential economic and social benefits of creating safe and inviting outdoor spaces for after-dark activities.

Studies of nightscape design have taken a variety of research approaches. For example, ZAKI & NGESAN (2011) suggested the use of space syntax analysis to understand peoples' behavior in nighttime environments. AHN et al. (2007) investigated the characteristics of streetscapes at night using factor analysis, correlation analysis, and cluster analysis. They found that "harmonious" and "vibrant" were the main characteristics of successful nighttime urban spaces.

Another important area of study regarding nighttime environments is fear responses to nighttime environments. Higher levels of fear among potential users can inhibit the use of nighttime landscapes. In previous studies (e.g., KING & CRANSTOUN 1989; FISHER & NASAR 1992; KOSKELA & PAIN 2000), researchers have identified fear as one of the main social issues directly affecting nightscape use, and they suggest that environmental design guidelines are needed to decrease levels of fear.

Although the sense of fear or danger has many causes, one potential source of fear is the design of the physical environment (NASAR et al. 1993). At the site scale, some researchers (e.g., NASAR et al. 1993; NASAR & FISHER 1993; PAINTER 1996; HERZOG & MILLER 1998; BLOBAUM & HUNECKE 2005; JORGENSEN et al. 2013; BOOMSMA & STEG 2014) have investigated how people perceive fear or danger by comparing their behaviors with the physical environment. FISHER & NASAR (1992), in particular, examined fear of crime in relation to outdoor sites that varied in in terms of their affordance of prospect, refuge, and escape. These previous studies, however, have lacked objective assessments of the landscape characteristics or conditions that elicit fear.

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Recently, eye tracking has become a popular research tool in the development of objective measures of human responses to visual stimuli. Eye-tracking studies have been used extensively in the design of user-friendly computer interfaces, and this approach has more recently been adopted in fields such as marketing, psychology, neurology, and cognitive neuroscience. Although this method is rarely used in the field of environmental design, the possibility of adapting eye-tracking methods to this field has been demonstrated in the previous studies (PARK 2010; KIM & KIM 2012).

In this study, we attempt to build on these prior efforts to investigate people's fear responses to different outdoor nighttime environments using eye-tracking technology, with the ultimate goal of contributing to the development of nightscape design guidelines. Furthermore, the use of eye-tracking goggles in this study represents a new application of eye-tracking technology to the study of nightscapes – one that allows for the study of eye movements in response to real outdoor environments (referred to as *actual environments* throughout this study), as well as simulated images or photographs of nightscapes (referred to as *image-based environments* throughout this study). Furthermore, comparison of our study results in actual environments with those of a prior eye-tracking study using image-based environments provides a means of examining the validity of image-based studies.

2 Method

Phase 1 of this study involved collecting data on the eye movements and fear responses of participants viewing six nighttime landscapes in person using eye-tracking goggles. In Phase 2 of the study, this data was compared with data previously collected by the researchers on the eye movements and fear responses of participants viewing photographs of the same six nightscapes. The study is based on two assumptions:

Assumption 1: People might feel different levels of fear depending on the arrangement of trees, lighting, shrubs, buildings, and so on in their physical environment.

Assumption 2: Perceived fear would be slightly different in actual environments than in image-based environments.

Phase 1 of this study involved tracking participants' eye movements when viewing six actual nighttime environments and then asking them to rate the level of fear felt in each environment. The six environments used in this study were located on the Virginia Tech campus in Blacksburg, Virginia, USA, and were previously identified and photographed for the image-based eye-tracking study that provided the comparison data used in Phase 2 of this study. The six nightscape images selected (see Figure 1) were chosen from 30 photographs of different types of campus environments by Virginia Tech faculty in landscape architecture. All images were taken during early fall on the Virginia Tech campus. As seen in Figure 1, Photo E1 depicts an open environment with unrestricted views. Photo E2 shows an enclosed environment with stairs and several trees, and Photo E3 describes an enclosed environment surrounded by shrubs. Photo E4 is enclosed by landscape structures, and Photo E5 depicts a lighted, paved path vanishing into darkness. Finally, Photo E6 depicts an enclosed environment in front of a building. The same types of lights are used throughout the campus. However, there is one minor factor that varies, slight variations of the intensity of illumination which is caused by the different ages of lamps.

Fig. 1: The six nightscape environments chosen for this study

2.1 Eye-Tracking Apparatus

The study used an eye tracker analysis system and eye-tracking goggles that can be used outdoors made by SensoMotoric Instruments (SMI). These devices and the Begaze2 software provided a powerful platform for recording and analyzing gaze-tracking data. A video camera built into the goggles allowed investigators to see and record what study participants saw. The goggle's sensors can detect a variety of eye movement characteristics, such as fixation count, areas of interests (AOIs), and scan path length.

2.2 Participants

A total of 26 people participated in this study, ranging from 19 to 43 years of age (M = 24.92, SD = 5.53). Of these, 14 participants (53.85%) were male and 12 (46.15%) were female. All participants were undergraduate or graduate students at Virginia Tech and came from a variety of academic majors. The data of three participants could not be analyzed because their eyes could not be correctly fitted in eye-tracking goggles. Thus, we collected valid data from 23 participants. Roughly the same individuals participated in both phases of this study (viewing image-based nightscapes and the actual nightscapes).

2.3 Procedure

In Phase 1 of this study, participants were fitted with eye-tracking goggles and asked to view in person six different nighttime landscape scenes on campus. They were also asked to rate the sense of fear or danger elicited by each environment. Before beginning data collection with each participant, one of the investigators informed him or her about the general study procedures and study objectives. Then the eye-tracking goggles were fitted to the participant's head and the head strap tightened to ensure a firm fit. The goggles were calibrated to each individual's eyes. With the goggles properly fitted, one of the investigators took each participant to the six nighttime landscapes shown in Figure 1.It took approximately 30 minutes to collect data from each participant. At each site, participants were instructed to look at the scene in front of them for almost eight seconds (Figure 2). Participants were not given any specific instructions on what to look at within each scene. Once all six eye-tracking trials were completed, participants were asked to rate their feelings of fear at each site on a 7-point Likert-type scale (where 1 = *very fearful*, and 7 = *very safe*). It took approximately 30 minutes to collect data from each participant. The final step in Phase 1was to analyze the collected eye-movement data. In eye-tracking studies using goggles, unlike other eye-tracking methods, semantic gaze mapping is used to convert eye movements into dotted lines on reference images (Figure 3). After transferring the recorded eye movements onto the appropriate reference images, the data were analyzed.

Fig. 2: Data collection at the six nightscapes

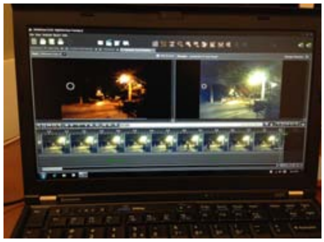

Fig. 3: The process of semantic gaze mapping

2.4 Measurement

The main dependent variables were the mean fixation counts for the six nightscapes in this study. Pupil size and scan path length were also analyzed. To visualize how participants' gazes were fixated and moved, heat maps were generated and AOIs were identified. All data were extracted from the video data and analyzed using Begaze2 software. Table 1 defines the various eye movement measures used in this study.

Consistent with other nightscape studies (e.g., Fisher & Nasar 1992; Painter 1996; Knight 2010), fear was chosen as our main variable in the analysis of nightscape characteristics. Our study used a quantitative approach, which aimed to compare each nightscape's characteristics objectively using mean averages, analysis of variance (ANOVA), correlations, and t-tests. T-tests, in particular, were carried out on the mean ratings of fear in order to determine whether there were any significant differences in participants' fixation counts between the actual environments and the image-based environments.

Table 1: Summary of eye movement measures used in this study

Measure	Description
Fixation count (avg.)	Total number of all fixations (i.e., where the eyes pause)
Pupil size (avg. px)	Average size of pupil
Heat map	Visual representation of the amount of time spent looking at different areas of a stimulus image
Scan path length (avg. px)	Sum of the lengths (distance from start to end) of all the saccades in the scan path

3 Results

3.1 Fear

The major findings regarding fear responses to the six nighttime environments used in this study are presented in Table 2, which contains the mean fear rating for each actual and image-based nightscape. There were differences in levels of perceived fear between the actual environments and the image-based environments. Nightscape E4, which contained mainly hard landscape structures, was identified as the most secure environment (*M* = 5.27) of the six actual locations. Conversely, E1, depicting an open setting, was rated most frightening (*M* = 4.31) among the actual environments. However, when participants viewed the photographs of these environments, E2 (stairs, light, etc.) was regarded as the least frightening location (*M* = 5.43), and E5 (apaved path with lighting) was the most frightening location (*M* = 3.13). It should be noted that overall, participants rated the image-based environments as less frightening than the actual environments. The only exception to this was E2.

Table 2: Mean fear ratings for each image-based and actual environment

		E1	E2	E3	E4	E5	E6
Actual environment	*M*	**4.31**	5.08	5.23	**5.27**	4.85	4.92
	SD	1.52	1.92	1.63	1.61	1.49	1.55
Image-based environment	*M*	3.61	**5.43**	3.83	3.83	**3.13**	4.43
	SD	1.12	1.08	0.78	0.98	0.92	0.99

Participants reported their level of fear for each actual location and each location image for (previous study) on a 7-point Likert-type scale, where 1 = *very fearful* and 7 = *very safe*.

T-tests were conducted in order to compare the results for the actual environments with those of the image-based environments (Table 3). The results were statistically significant ($p > .001$) for E3, E4, and E5. This indicates that the trend people perceive fear would be similar on the locations (E1, E2, E6). Contrary to this, the perceived fear of E3, E4, and E5 were recognized differently. In short, reported different fear levels in the actual environments versus the image-based environments depending on environment, and people tended to feel more fear in response to actual environments than image-based environments overall.

Table 3: Results of *t*-tests on mean fear ratings

	t	***df***	***p*value**
E1	1.816	47	.076
E2	-0.817	40.267	.419
E3	3.914	36.726	.000*
E4	3.826	42.000	.000*
E5	4.912	42.286	.000*
E6	1.295	47	.202

$p > .001$

3.2 Eye Movement Results

Table 4 summarizes the results of the eye movement analyses for fixation count, scan path length, and pupil size in both phases of the study. For the actual environments, E5 (paved path with lighting) had the highest average fixation count (20.76) among all locations. E5 also had the greatest scan path length (i.e., total length of saccades; 715.38). This may indicate that fixation count has a positive relationship with scan path length from previous result. We found additional positive relationships between them ($r = .598$, $p = .000$) using a Pearson's correlation analysis. Study results also indicated that participants' pupil sizes increased most when viewing location E3 in person (95.72).

Table 4: Results of eye movement analysis

		E1	**E2**	**E3**	**E4**	**E5**	**E6**
Actual environ ment	Fixation count (avg.)	19.17	20.38	19.18	19.00	**20.76**	20.38
	Scan path length (avg. px)	521.22	576.18	530.41	650.35	**715.38**	685.10
	Pupil size (avg. px)	93.35	77.77	**95.72**	79.27	81.69	79.45
Image-based environ ment	Fixation count (avg.)	13.61	**19.78**	14.61	14.96	13.70	10.78
	Scan path length (avg. px)	2157.78	**3422.48**	2192.22	2864.04	2776.30	1588.87
	Pupil size (avg. px)	15.05	15.67	14.61	**16.54**	15.12	15.96

The results for the image-based environments differed slightly from the actual environment results. Participants' eyes fixated the most on image E2 (19.78), which also elicited the longest scan path lengths from participants (3422.48). Image E4 depicted an environment surrounded by hard landscape structures and had the largest pupil size results among the six images. The authors could find another results in which the average scan path length and pupil size were quite different between the actual and image-based environments (Table 4). Correlations between eye movement parameters (fixation count, scan path length, pupil size) and perceived fear ratings were not statistically significant by Pearson's correlation analysis.

Meanwhile, an ANOVA test was carried out to find the differences in eye movement for the six actual environments. There were no statistically significant differences in fixation count and scan path length among the different environments. The results for pupil size, however, found statistically significant differences for the six environments (p = .12). This indicates that pupil size can be a parameter for estimating people's fear responses to different nightscape settings.

3.3 Eye Movement Differences Between Actual and Image-Based Environments

Using the heat maps generated from the eye-tracking data, we identified the areas of interest (AOIs) in both the actual and image-based environments (Figure 4). For location E1 in actual environment, participants tended to focus on the central area and far end of the path, although the AOI for the actual environments was comparatively larger than for the image-based environments. The areas of fixation for E2 were the end of the path and the bottom of the front light for both the actual and image-based environments. In the case of E3, we found that the area of fixation was the center for both the actual and image-based environments, but the intensity of focus was slightly different. The fixated areas for E4 were also the center and the end of the path. The participants also focused on the right side of E4. For E5, and participants mostly focused below the central light fixture and on both sides of the path. Finally, for both the image-based and actual E6 environment, participants fixated primarily on the entrance to the building. In the actual environment, participants also focused to a lesser extent on the right. Interestingly, the authors found that areas of focus were highly similar between the actual environment and in image-based environment, although there were slight differences in terms of the size of the AOIs and the intensity of focus.

	Actual environments	Image-based environments
E1		
E2		
E3		
E4		
E5		
E6		

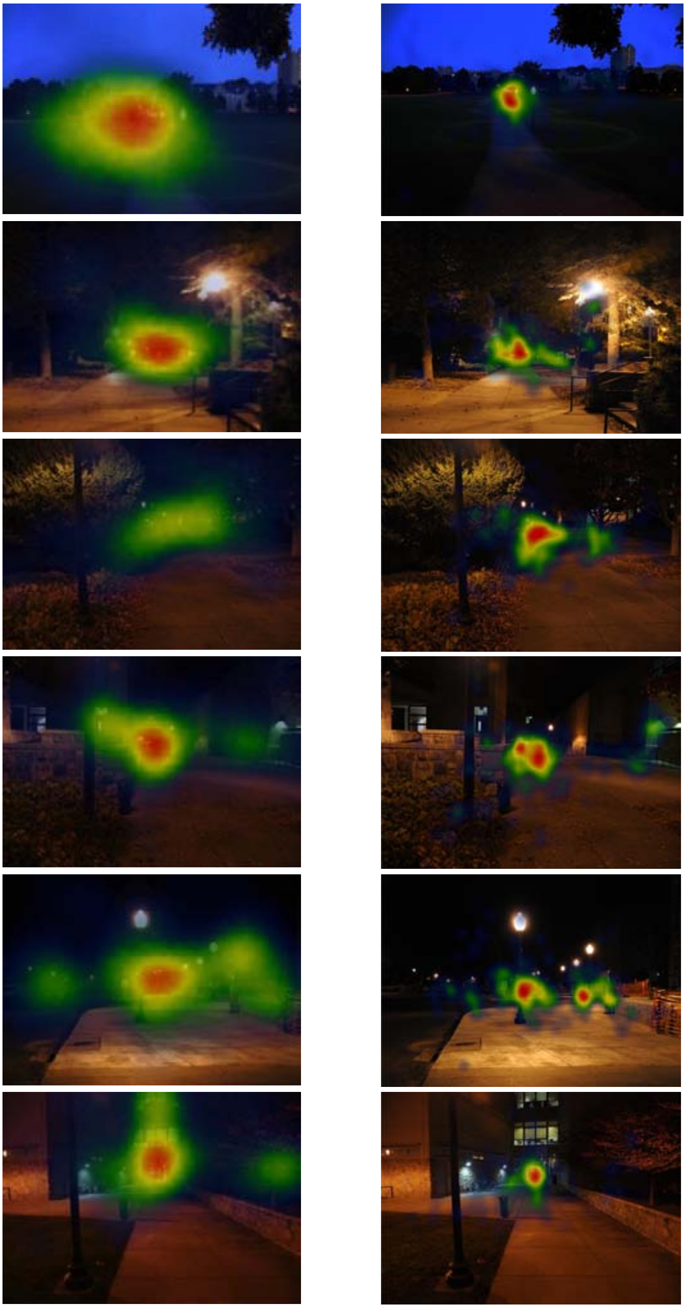

Fig. 4: Heat maps generated from participant data for each environment (in the actual and image-based environments)

4 Discussion and Conclusion

Fear of nighttime environments is one of the major barriers to the use of outdoor spaces after dark. Planners and other stakeholders concerned with nightscape planning, therefore, should consider how to reduce fear when planning for nighttime users. Fear can arise for many reasons, but the amount and brightness of lighting have been regarded as a main factor. Based on previous studies, other variables, such as landscape structures and built structures (e.g., FISHER & NASAR 1995; JORGENSEN et al. 2013; BOOMSMA & STEG 2014), can also be important for reducing fear. Thus, this study investigated fear responses and eye movements across six different nightscape environments.

The authors found that levels of reported fear differed in the six different types of night time environments. The location in which many participants felt the most fear was location E5 (paved path with light fixtures; Figure 1). This may be because people feel more fear when they cannot see where the path leads to. In comparing fear results between the actual environments and the image-based environments, participants tended to feel more fear when in the actual environments overall. The authors also found that the average scan path lengths and pupil sizes differed between the actual environments and image-based environments. In other words, we cannot directly compare the values calculated for the eye movement parameters (scan path length, pupil size, etc.) for the actual environments and the image-based environments.

Regarding the eye movement results, we initially found a relationship between fixation count and pupil size using Pearson's correlation. But there were no differences between perceived fear ratings and eye movement parameters (fixation count, scan path length, pupil size). Group differences in pupil size depending on the different environments were significant, which indicates that pupil size may be a parameter to predict the different responses toward the different types of nightscape environments. The most interesting findings were yielded by the heat map results. A comparison of the heat maps for the actual environments with those of the image-based environments indicated that people focused on the same areas of the environment. Only the intensity level and size of the focus areas differed slightly between the two studies. This suggests that eye-tracking research using image-based environments can be as effective as bringing participants to real environments. However, the authors suggest that eye-tracking in the actual environment can provide a more detailed understanding of fear in different types of nightscape design. While the exact same locations and the same light fixtures were used for the comparisons, it is important to consider that the image-based surveys were conducted in a darkened lab showing only the simulation of the actual environments. The only light source in the simulated environment was the monitor, not the actual street lights. Another detail that cannot be simulated by the image-based environment study is the fear people feel from other people in the same vicinity at night. While eye movement parameters provide a starting point for further research regarding the triggers of fear in the nightscape design, there are several details regarding fear the image-based environment study overlooks. Therefore, further studies will be conducted to investigate the specific areas of interests that were undetected by the image-based environment studies by getting additional information using questionnaires or interviews in order to analyze the perception of fear in greater detail.

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