Who Is Afraid of "Light"?

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1 Introduction

This study investigates the effects of outdoor lighting on people's perceptions of nighttime landscapes. More specifically, it examines the relationship between lighting and specific physical features of nighttime landscapes in participants' reports of fear. To accomplish this, a combination of eye-tracking and self-reported data were collected. This study ultimately presents design guidelines intended to reduce fear levels experienced in the nighttime landscape.

Fear has been identified as a prominent factor in nighttime experiences of the urban environment (e.g., NASAR, 1998). Concerns regarding nighttime safety and security led to a more brightly lit nightscape. Although abundant lighting has been shown to increase individuals' perceptions of safety, the present research postulates that the effects of outdoor lighting on the perception of danger is a complex phenomenon needing more detailed study. Whereas under-lit nightscapes tend to induce fear, over-lit spaces can also cause fear because bright lighting can make it difficult to discern features and details in the nightscape.

Many studies have examined the relationships between outdoor lighting, crime, and fear (e.g., AUSTIN et. al., 2002; ZAHM, 2004; PAINTER & FARRINGTON, 2005; PEASE, 1999). Although some studies have found that lighting improvement did not help reduce crime (e.g., QUINET & NUNN, 1998), many others indicate that, in general, increased lighting reduces crime and fear (e.g., PAINTER, 1996). Researchers have also studied perceptions of nighttime safety (e.g., KNIGHT, 2010; THOMAS & BROMLEY, 2000). Approaching from a social sciences perspective, these studies used crime statistics from large-scale areas. These studies lacked site design scale understanding of lighting and crime and did not include human perception of fear in the situation. At a smaller scale, FISHER & NASAR (1992) studied the relationship between fear of crime and site features with respect to refuge, prospect, and escape characteristics. They concluded that an absence of refuge for potential criminals (i.e., the absence of hiding places) and high prospect for others (i.e., the ability to visually survey one's surroundings) reduce the fear of crime among study subjects. Their study and similar ones following it, however, did not examine the specific landscape elements that influence people's fear of crime, particularly at nighttime. Because of the nature of the data and the large study areas, the factors of nightscape design in small-scale places, such as types and brightness of lighting, and landscape elements, could not be accounted for.

Within the design disciplines, most of the lighting design literature focuses on lighting aesthetics and largely ignores questions of safety or the perception of safety (WILSON, 1984; MUNCHEN, 1998; RAINE, 2001; MOYER, 2005).

The present research studies subjects' reported levels of fear in response to the interaction of lighting position and level with the presence of specific physical elements in the land-

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scape as viewed in photographs. This research studies participants' reported levels of fear directly corresponded to the interaction of lighting positions and the presence of specific physical elements in the landscape. The specific landscape elements addressed in this study are buildings, low, free-standing walls, tall and short trees, and shrubs. Additionally, the study examines the effects of the presence of a human figure in a nightscape, because the presence of a stranger in a nighttime landscape is suspected to elicit fear. The landscape elements above could increase or decrease level of fear. For example, FISHER & NASAR (1992) argued that although trees typically have restorative characteristics in daytime environments, they also provide "concealment, a limited prospect, and blocked escape routes [that] may increase fear at night" (FISHER & NASAR, 1993).

Although eye-tracking technology has been used rarely in landscape architecture research, it has been widely used in various fields such as market research, ergonomics, human behavior, psychology, education, neuroscience, and sports. LEE, TANG & TSAI (2005) studied color preference through eye tracking comparing combination colors. ITOH & FUKUDA (2002) studied eye movement in the extent of central and peripheral vision and use by young and elderly walkers. CUTRELL & GUAN (2007) used eye-tracking to examine eye-movement during Web browsing.

One of the significance of this study is that it used eye-tracking techniques to identify the specific elements in landscape photographs on which subjects' gaze rested and for how long in relation to fear. Unlike the above-mentioned studies that examined the overall image of a landscape, the use of an eye-tracking apparatus in this study provided a means of identifying the areas and objects within various nightscapes on which subjects focused their gaze while reporting that a landscape image elicited fear. By comparing the particular objects/areas of the photographs on which people focused, the sequence in which they focused on these objects/areas, and length of each focused gaze with reported levels of fear, specific physical elements of nighttime landscapes were identified.

2 Methods

The study described here tests two main assumptions about the sources of fear in the nighttime landscape:

Assumption 1: Physical elements in nightscapes, such as woods, shrubs, and man-made structures, will affect people's level of fear.

Assumption 2: If the other landscape elements are constant, the presence of an adult figure in the nightscape will increase fear.

2.1 Survey Instrument

In order to test these assumptions, a survey instrument containing nine digital photographs of three different nightscapes (three sets of three photos; see Figure 1). Photos in the first set (referred to as B1, B2, and B3) depicted a nightscape with a building in the background. The second set of photographs (T1, T2, and T3) depicted a nightscape with trees in the background. The third set (S1, S2, and S3) depicted a nightscape with landscape structures (i.e., retaining walls, sitting walls) in the background. Additionally, each set of photographs depicted three different conditions: the nightscape with no human presence, the nightscape with an adult male figure whose face was illuminated by site lighting, and the nightscape with an adult male figure lit from behind so that his facial features are not discernable. In the latter two conditions, the individual was centered in the frame, 3 meters from the camera. All photos were taken on the Virginia Tech campus in Blacksburg, Virginia.

Fig. 1: Images used for the experiment (three sets of three). The image set in the top row (B1-B3) has a building in the background, the middle set (T1-T3) has vegetation in the background, and the bottom set (S1-S3) has landscape structures in the background. Each image set presents one image without the presence of a person (left column), one with a light source behind the person and his face in shadow (middle column), and one with the person's face lit (right column).

2.2 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 Senso-Motoric Instruments (SMI) of Germany (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 researcher and research participant were present in the lab.

Fig. 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.

2.3 Participants

The participants consisted of 15 male and 11 female students and professors at Virginia Tech. Two men and one woman were eliminated from the study because of irregularities, leaving a total of 23 experiment participants of various disciplinary backgrounds.

2.4 Procedure

At the beginning of each session, participants were informed about the purpose of the study and the experimental procedure. Next, the eye tracker was calibrated to each participant's eyes by asking him or her to follow a red circle on the monitor with their eyes. In order to minimize distractions for participants, all lights in the lab were turned off during each session.

Participants were shown nine digital photographs (three different nightscapes with three different conditions; see 2.1 Survey Instrument) in a random order. Images appeared on the computer monitor one at a time. As participants viewed each image, they were asked by the researcher to rate (by typing into the computer) their level of fear on a 7-point Likert-type scale, where 1 is very fearful and 7 is very safe. No further elaboration on these instructions were given by the researcher. Participants were permitted to view each image for as long as they wanted before pressing the spacebar to rate their level of fear on the screen. Once they recorded this number, the monitor automatically advanced to the next, randomly selected image.

After rating their level of fear for each photograph, participants were asked to fill out a brief paper survey that recorded demographic information. Each session took about 30 minutes.

2.5 Measurement

To analyze participants' eye movements for each image, the investigator examined the eye-tracking data for the total duration of gaze for each image and each participant's fixation duration (ms), and saccade counts (see Table 1 for a summary of terms used in the paper). Total duration of gaze measured the total time a participant spent looking at an image before moving to the next image. Fixation duration measured the time spent looking at particular points or areas within a single image. Saccade counts accounted for eye movements between fixation points. Additionally each image was divided into areas of interest, such as a building, a structure, trees and grass, a concrete path, and the human figure, by tracing the edges of each of these elements in the Begaze2 software. Investigated next was the area of interest (AOI) coverage (%), AOI net dwell time (ms), AOI fixation count, and AOI revisits count.

To analyze fear and eye movement differences, an analysis of variance (ANOVA) was performed for the nine sets of images.

Table 1: Summary of terms used in the paper*

Terms	Description
Total duration	Total time that each participant spent viewing each image
Fixation duration	Total time of all fixations (no movement)
Saccade	Eye movements as the gaze travels from one point of fixation to another
Saccade count	Number of saccades
Scan path	Gaze positions and eye movement plotted on the stimulus image
Pupil size	Average size of a pupil
Heat map	Visual representation of time spent looking at different areas of a stimulus image
AOI coverage	The percentage of each AOI on an image
AOI net dwell time	Sum of all fixations and saccades within an AOI for all subjects
AOI fixation count	Number of fixations for selected subjects divided by the number of selected subjects
AOI revisits count	Number of revisits recorded when an AOI is revisited at least once.

*Definitions follow SMI (2012). All terms are per a participant for an image.

3 Results

3.1 Fear

The results comparing means of fear levels for the nine images showed that most participants tended to feel more fear while viewing nightscapes with structures (not buildings)

(Table 2). Image S2 found in Figure 1 (Structure type with a person's face in shadow) was the most feared image (mean: 2.70). On the other hand, the image rated safest among the nine images was T1 (a tree in the background, with no human figure present; mean: 4.43). An analysis of variance (ANOVA) was performed to confirm whether the level of fear was affected by the environment type (i.e., building, tree, and structure). Although the intensity of illumination, the size and height of the light fixtures were the same within each of the three photo sets, the results showed significant differences among the three environment types regarding the mean of fear levels ($F = 61.942$, $p < 0.05$).

To determine whether fear levels were affected by the presence of a human figure, another ANOVA was conducted. For the building type (B1, B2, B3), there were significant differences among the conditions: (1) without a human figure, (2) with a person whose facial features are lit, and (3) with a person whose facial features are in shadow ($F = 101.246$, $p < 0.000$). There were also significant differences in the condition for the Structure type (S1, S2, S3) ($F = 80.638$, $p < 0.000$). However, no significant differences were found among the images with the Tree type (T1, T2, T3). Overall, regardless of the location of the light source, images containing a person were feared more than images without a person.

Table 2: Participants' mean fear ratings for each photograph

	B1	**B2**	**B3**	**T1**	**T2**	**T3**	**S1**	**S2**	**S3**
Mean	4.43	2.96	3.13	3.83	3.78	4.00	3.83	2.70	3.70

Participants reported their level of fear in response to each image on a 7-point Likert-type scale where 1 = very fearful and 7= very safe.

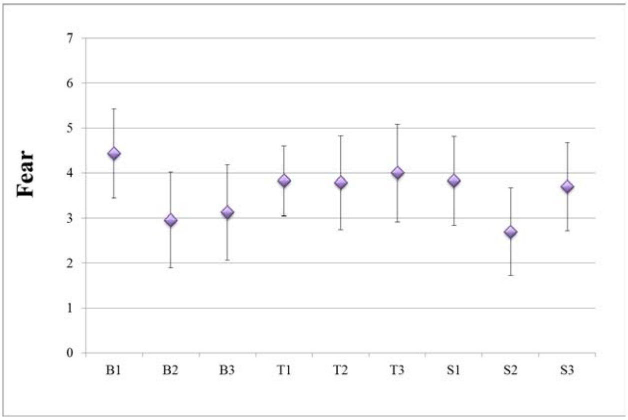

Fig. 3: Mean levels of fear (squares) and standard deviations (vertical lines) for the nine images

3.2 Eye Movement Results

Although the results above could be found with traditional visual preference study methods using slides, one goal of this research was to determine if an eye-tracking apparatus could be used to more accurately understand why subjects felt a particular level of fear. The eye-tracking results for the three environment types are summarized in Table 3.

For the eye movement results, the investigator analyzed subjects' eye movements using fixation duration, saccade count, scan path length, pupil size, and total duration. In general, when a human figure appeared in the images, subjects focused on the person's face more, regardless of whether his facial features were illuminated or obscured, whereas for the images without a person, subjects' foci were more scattered.

Table 3: Results of eye movement analysis

Image Back-ground	Type	Fixation duration (avg. in ms)	Saccade count (avg.)	Scan path length (px)	Total duration (avg. in ms)	Pupil size (px)	Fear rating (avg.)
Building (B)	No human present (B1)	222.34	10.70	1588.87	3211.17	15.96	4.43
	Adult male present (lit from behind) (B2)	284.43	10.09	1307.70	3993.91	16.50	2.96
	Adult male present (lit from the front) (B3)	304.63	12.61	1600.74	4804.74	16.65	3.13
Tree (T)	No human present (T1)	220.24	15.91	2192.22	5543.43	17.53	3.83
	Adult male present (lit from behind) (T2)	308.04	7.65	1092.96	2895.61	16.26	3.78
	Adult male present (lit from the front) (T3)	323.79	8.39	1070.91	3275.70	16.74	4.00
Structure (S)	No human present (S1)	198.20	16.61	2864.04	5312.35	16.54	3.83
	Adult male present (lit from behind) (S2)	276.90	7.30	1034.04	2443.22	16.56	2.70
	Adult male present (lit from the front) (S3)	259.55	9.39	1309.39	3107.13	16.07	3.70

For Tree and Structure type images, when a person was not present, subjects tended to spend more time looking at the landscape (total duration) when compared to other images with a person. For fixation duration, S3 had a higher number, suggesting that when a human figure appeared in a photo, subjects spent more time looking at the facial features of the person. Saccade count tends to have an inverse relationship with fixation duration because the participants spent more time looking at fixed objects than moving their gaze. Building type was an exception for an unknown reason.

Image Set B (Building)

After completing the overall analysis of eye movements, AOIs were analyzed in order to identify areas that received more attention from subjects (Table 4). The investigators first divided each image into AOIs, such as those shown in Figure 4.

Table 4: Notable factors of AOI for the Building type

Image		**AOI coverage (%)**	**Net dwell time (avg. in ms)**	**Fixation count (avg.)**	**Revisits count (avg.)**
Background only (B1)	Building	26.6%	1444.8	4.9	1.3
	Structures	4.2%	133.0	0.4	–
	Trees and grass	24.5%	250.2	1.0	–
	Concrete path	23.1%	1012.6	3.6	1.0
Adult male present (lit from behind) (B2)	Human	5.2%	2434.5	6.1	1.4
	Building	24.8%	515.0	1.3	–
	Structures	3.5%	195.4	0.7	–
	Trees and grass	26.8%	248.7	0.7	–
	Concrete path	18.8%	222.0	0.5	–
Adult male present (lit from the front) (B3)	Human	4.9%	2470.5	6.6	2.3
	Building	24.1%	458.1	1.5	0.1
	Structures	3.3%	47.9	0.0	–
	Trees and grass	25.2%	253.5	0.8	–
	Concrete path	19.6%	604.2	1.9	–

For the Building type, when a figure's face was illuminated (B3), subjects' gaze was more focused than when the figure's face was obscured by shadow for all three conditions. The heat maps in Figure 5 show accumulated time spent looking at different areas of the stimulus image for different conditions. Scan path maps in Figure 5 show gaze positions and eye movement path. While heat maps are good for showing areas of attention, scan path maps are good for depicting scattered eye movement.

The image without a human figure (B1) indicated that subjects were mostly interested in the building (fixation count: 4.9; dwell time: 1,444.8 ms) and the concrete path (fixation count: 3.6; dwell time: 1,012.6) when compared to other parts of the image. The building in the same image (B1) also recorded 1.3 revisits, which suggests that people wanted to return to the spot in which they were interested earlier. When a human figure was present in the photos (B2, B3), subjects were more interested in the figure's face than to landscape elements or structures.

Fig. 4: An example of area of interest (AOI) delineation and statistics for image T2. The image on the left was derived from the right-side image.

In addition, whether or not the facial details were visible showed significant impact on subjects' eye movements. When the figure was back-lit and their features were obscured (B2), the building was the second most interesting element (fixation count: 1.3) following the figure in the image. However, when the figure's face is illuminated (B3), it was found that the concrete path was the second most interesting factor to most subjects, after the figure. When a person is in an image (B2, B3), AOI coverage values were significantly smaller and more focused (B2: 5.2%; B3: 4.9%), while the net dwell time, fixation counts, and revisit counts were high. This means that a person's presence in an image is an important factor affecting subjects' evaluation of nightscape.

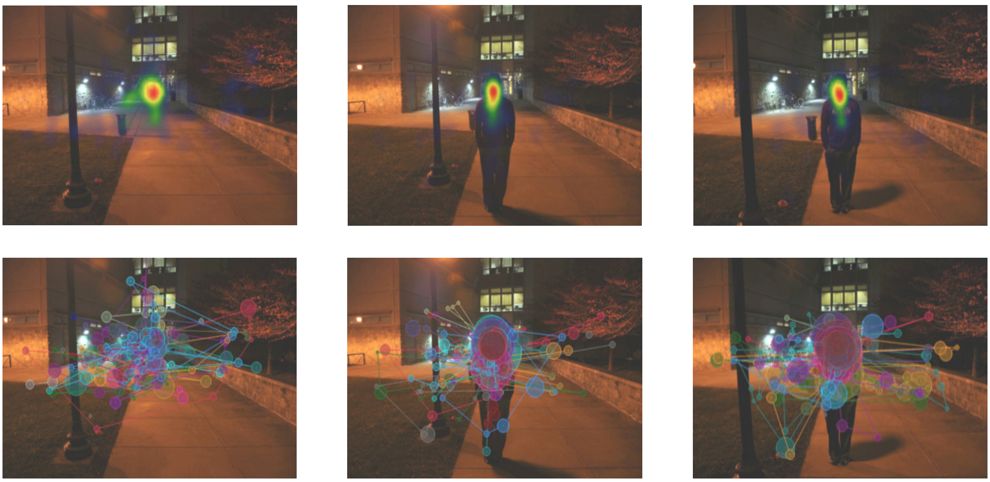

Fig. 5: Heat maps and scan paths for Building type

Image Set T (Trees)

For the image with a tree in the background (T1, T2, T3), subjects focused more on the figure when his face was illuminated (fixation duration: 323.79 ms) than on other elements on the image. The image with no human figure (T1) received the lowest fixation scores, as subjects showed more scattered scan path patterns (scan path length: 2192.22 px) (Figure 6, Table 5). The image also elicited the lowest fear levels of the three images (T1, T2, T3). The investigator suspects that when a person fears an element, they spend more time focusing on that object.

For an AOI analysis, the images were divided into areas of building, structure, tree and grass, concrete path, and human figure as appropriate. It was found that almost all subjects focused on the human figure. The net dwell times and fixation counts were the highest when a human figure was present (net dwell time of T2: 1601.2, fixation count of T2: 4.2, net dwell time of T3: 1833.3, fixation count of T3: 4.5).

The investigators have also found that when the figure's face was in shadow (T2), the second most focused upon area was the concrete path (fixation count: 1.4). When the figure's face is lit, the second most focused upon areas were trees and grass (fixation count: 1.3). Just like in the Building type, the location of the light relative to the figure's position made the difference in subjects' second most important areas of interest.

Fig. 6: Heat maps and scan path for Tree type

For the Structure type, as in the other two types, subjects spent more time on fixed areas when an image included a human with a back to the light (S2 and S3) than on other areas (fixation duration: 276.90) (Figure 7, Table 6). The lowest score of the fixation was recorded when the image was without a human (S1) as was in the other two types. Scan path length and total duration were the highest in the condition without a human (scan path length: 2864.04, total duration: 5312.35).

Table 5: Core contents of AOI

		AOI coverage (%)	Net dwell time (avg. ms)	Fixation count (avg.)	Revisits count (avg.)
Background (T1)	Building	1.5%	289.7	1.0	–
	Structures	23.2%	190.7	0.8	–
	Trees and grass	47.6%	1158.0	3.9	0.4
	Concrete path	23.2%	2093.3	7.2	2.0
Human with a back to the light (T2)	Human	4.9%	1601.2	4.2	1.2
	Building	0.9%	38.8	–	–
	Structures	2.1%	63.8	0.3	–
	Trees and grass	47.1%	378.2	1.1	–
	Concrete path	19.6%	419.6	1.4	–
Human facing the light (T3)	Human	5.3%	1833.3	4.5	1.5
	Building	0.9%	59.5	0.3	–
	Structures	3.1%	39.6	0.2	–
	Trees and grass	46.1%	427.5	1.3	–
	Concrete path	19.3%	59.5	0.3	–

Image Set S (Structure)

For an AOI analysis, the areas of the image were divided into building, structure, tree and grass, concrete path, and human (except S1). It was found that almost all subjects focused mainly on the human as in previous two cases. The net dwell time and fixation counts were highest when a human is added to the image (net dwell time of S2: 1184.0, fixation count of S2: 3.6; net dwell time of S3: 1713.3, fixation count of S3: 5.2). When a human is not present in the image, subjects focused on the concrete path than on other areas. When a human is present (S2 and S3), the second most focused area was the building in the background (fixation count of S2: 2.0; fixation count of S3: 2.3).

Fig. 7: Heat maps and scan path of the condition surrounded with structures

Table 6: Core contents of AOI in the condition surrounded by structures

		AOI coverage (%)	Net dwell time (avg. ms)	Fixation count (avg.)	Revisits count (avg.)
Background (S1)	Building	32.0%	2074.0	7.4	2.1
	Structures	2.8%	228.9	0.9	–
	Trees and grass	14.3%	235.0	0.7	–
	Concrete path	25.3%	1319.1	5.2	1.4
Human with a back to the light (S2)	Human	4.5%	1184.0	3.6	1.0
	Building	21.0%	546.6	2.0	–
	Structures	2.4%	92.8	0.3	–
	Trees and grass	22.5%	30.8	0.1	–
	Concrete path	23.1%	275.6	0.9	–
Human facing the light (S3)	Human	4.8%	1713.3	5.2	1.8
	Building	31.6%	666.9	2.3	0.8
	Structures	4.4%	60.1	0.3	–
	Trees and grass	10.7%	11.6	–	–
	Concrete path	21.7%	194.0	0.7	–

4 Discussion and Conclusion

Perceived fears of nighttime spaces have been studied previously (e.g., Fisher and Nasar, 1992). However, these studies did not investigate the relationship between fear and specific physical elements in the nightscape. This study builds on these prior studies by analyzing people’s gaze into various parts of nightscape images.

This paper investigated the effect of elements in the nightscape and lighting on people’s perception of nightscapes. Evaluations of nine different nighttime situations were conducted to verify assumptions that the degree of fear study participants reported when viewing nightscape photographs would correlate to their eye movement.

Through this study, the investigator learned that reported levels of fear were affected by the different situations in the photographs. Almost all participants felt more fear when a human figure appeared in an image, regardless of the background type. The results showed that participants felt more fear when the human figure’s facial features were obscured by backlighting compared to the figure whose face was illuminated. This is likely because participants were not able to see the facial features of the individual and could not evaluate whether or not he was a threat. The investigator also could speculate that the higher the degree of fear, the shorter the distance of eye movement from the main points of interest of each image and the tendency of eye movement. In addition, when a human figure is added to an image, the intensity, frequency, and dwell time of focused gaze toward the human-being were increased greatly. This study suggests that to make the nightscape safe, it is important to light spaces evenly so that facial features are always visible.

A limitation of this study could be the relatively low number of participants. However, many other eye-tracking studies have had fewer number of subjects and still had meaningful results. Also because the experiment is done in a lab setting, the level of fear in a real outdoor environment could not be simulated. Wearable eye-tracking goggles might solve this problem. Future studies by the author plan to use these goggles.

The results of this study could help designers create safer nighttime environments through a growing understanding of the elements and conditions in nighttime landscapes that elicit fear. This knowledge will help add to nighttime design guidelines. Future studies might investigate other aspects of the perception of nighttime space to understand what people perceive as a preferred environment and not just fear.

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