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Article

Use of Electroencephalography (EEG) for the Analysis of Emotional Perception and Fear to Nightscapes

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Abstract: As the necessity for safety and aesthetic of nightscape have arisen, the importance of nightscapes (i.e., nighttime landscape) planning has garnered the attention of mainstream consciousness. Therefore, this study is to suggest the guideline for nightscape planning using electroencephalography (EEG) technology and survey for recognizing the characteristics of a nightscape. Furthermore, we verified the EEG method as a tool for landscape evaluation. This study analyzed the change of relative alpha power and relative beta power and self-reporting of participants in order to investigate the correlation between EEG and fear according to twelve nightscape settings. Our findings indicated the corresponding measures of fear vary accordance with whether there was people or not, and the environmental settings (Built Nightscape Images; BNI vs Natural Nightscape Images; NNI). Based on our physiological EEG experiment, we provided a new analytic view of the nightscape. The approach we utilized enables a deeper understanding of emotional perception and fear among human subjects by identifying the physical environment which impacts how they experience nightscapes.

Keywords: EEG, Psychophysiological responses, Landscape Evaluation, Nightscapes, Sustainable Landscape Design, Fear, Night Pollution

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1. Introduction

1.1. Back Ground

As the necessity for safety and aesthetic of nightscape have arisen, the importance of nightscapes (i.e., nighttime landscape) planning has garnered the attention of mainstream consciousness. Many local governments are recognizing that well-designed nightscapes can enhance an image of city and subsequently attract more residents, investors, and tourist. From an urban planning point of view, there is a difficulty to reconcile conflicts and interests between producers of light (beneficiary) and consumers, to draw consensus of the community, and to reflect these in light pollution standards and management systems. In this context, research on nightscape has been carried out in various disciples. However, the preceding studies mostly have focused on a particular structure to conduct a field survey rather than on empirical data [1]. Experimental data of nightscape is significant for human health as excessive lighting can cause fatigue, cause serious illness like cancer, and cause accidents [2].

Experiential data reflects the psychological elements of the participants. Since more 70% of the human senses were obtained visual sense among human's five representative senses, a lot of studies [3, 4] have been conducted to analyze emotions aroused from visual stimuli. Therefore, it is important to study psychological aspects among the effects of lighting on the human body, such as concentration, nervousness, and fear [5]. This study validates the relationship between nighttime environments and fear as one of the affective response to nightscape. We examine participants' report

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levels of fear directly corresponded to the interaction of lighting positions and the presence of specific physical elements in the landscape.

In this study, we attempted a new method of analyzing nightscape using Mobile electroencephalography (EEG) that are directly related to people's perception of the environment. The existing studies do not directly evaluate the EEG response to nightscape in combination with a survey analysis to assess human perception. Recent laboratory-based neuroimaging studies indicate that various environments may be associated with characteristic patterns of brain activity [6, 7, 8]. Mobile EEG provides a non-invasive way to capture emotional states of the human research subjects. Furthermore, research that utilizes Mobile EEG require rigorously controlled experiments and complex analytical tools. Mobile EEG is increasingly being used beyond the clinical and experimental environments; it is now frequently used to monitor brain function and cognition in real life situations [9]. A unique aspect of Mobile EEG its ability to gather the participants' response data on a second-by-second timescale with virtually no interruptions [10]. Recent Mobile EEG research shows how people can evaluate, visualize, explore, and develop a spatial perception of architectural designs [11].

The purpose of this study is to suggest the guideline for nightscape planning using EEG technology and survey for recognizing the characteristics of a nightscape. Furthermore, we verify the EEG method as a tool for landscape evaluation. We used survey methods to investigate participants' subjective perception of fear level to help interpret EEG data in a real-world setting by using mobile EEG apparatus. While EEG output provides a real-time psychophysiological measurement of response to changing environments, self-reporting of fear provides a context and understanding of these changes.

1.2. Studies on Nightscape and Desirable Landscape Types for Nightscape Studies

A number of previous studies on landscape perception have been associated with measuring how people perceive specific surrounding environmental settings during the daytime. Most of these studies have derived design guidelines following each finding. Nighttime design guidelines, however, for a particular environmental setting have not been as well developed as nightscape perception research. [12] analyzed subjective characteristics of light in nightscapes and studied the relationship between lighting design and people's perceptions of nightscapes. [13] attempted to evaluate nightscapes by identifying variables that affect people's perception of nighttime streetscapes. [14] studied the maintenance and improvement of nightscapes through field surveys. Most of these studies used qualitative methods.

Research has discussed the interplay between landscape types and the physiological response of human beings [15], it is very critical to divide landscape types in landscape evaluation studies. It is common to divide by dichotomy; natural versus built landscape in existing studies [16, 17, 11, 18, 10], but there have been various ways to divide landscape types in previous studies. [19] divided landscape types into six; plant environment including trees and other vegetation; water environment, primarily flowing water and that which involved trees; congested traffic; normal traffic; crowed pedestrian environment; and common pedestrian environment. [6] divided landscape types more specifically depending on the wildness level; extensive landscape such as mountain, small landscape such as Japanese gardens, and abstract landscape such as a view from window. Like this, landscapes from daytime can be divided into various ways, because people can perceive the detailed differences from them. However, landscape type from nighttime (nightscape) should be differently considered when it comes to arousing fear and its observability. [20] argued that daytime environments such as tree can increase fear at night because it provides concealment, limited prospects, and blocked escape routes. Moreover, the detailed landscape types in landscape evaluation research make it difficult for people to distinguish landscapes.

Therefore, the specific landscape types in this study were divided into natural and built landscape including buildings, low, free-standing walls, tall and short trees, and shrubs. Additionally, we investigated 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.

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1.3. Studies on EEG

EEG has been used as a tool to supplement surveys or experts' opinion that have been commonly utilized in landscape evaluation field. Recent studies using neuroimaging methods in environmental psychology studies have shown that different types of urban environments interact differently with varying environments in relation to the distinctive patterns of brain activity [10]. Existing studies using EEG in this way have explored how people perceive different environment settings, and these studies [6, 11, 10] mainly compared the natural landscape versus built landscape among various settings (see details in Table 1). For example, [11] investigated EEG how the brain engages with natural versus urban setting, suggesting that natural based landscapes were associated with greater levels of meditation and lower arousal than urban scenes. [10], in particular, measured the level of excitement, engagement, and frustration using EEG depending on specific urban and natural settings (Eight types of environmental settings. It also proposed a detailed design implication that compares EEG results with different settings.

As presented above, differences in perceived color [21], fractal pattern [22], and biodiversity [23, 24] as well as differences in brain activities by landscape type have been discussed in previous studies. In particular, [21] used EEG to derive a design implication that alpha wave can be used to create a peaceful space for alpha sound and to create lively spaces using beta waves. Here, the various brain wave such as alpha and beta wave are used to evaluate brain activity by proxy measurements. The measurement of brain activity can be divided into four types in general: Delta (< 4Hz) features slow and loud brainwaves and is generated in deepest meditation and dreamless sleep; Theta (4-7 Hz) occurs most often in light sleep or extreme relaxation; Alpha (8-13 Hz) is dominant during quietly flowing thoughts and in some meditative states; and Beta (14-30 Hz), which dominates our normal waking state of consciousness when attention is directed towards cognitive tasks [25].

As the recent EEG technology develops, the use of mobile EEG has been widespread in related studies, and new approaches combing different methodologies such as eye tracking [26], electromyography, and blood volume pulse [6], and in-depth interview [10] with EEG are also increasing to validate EEG's effectiveness. In addition to EEG technology, fMRI (functional Magnetic Resonance Imaging), another technology for measuring brain activity, has been used to compare landscape characteristics in other studies [27, 15]. [27] used functional MRI in response to viewing rural and urban living environment, which suggested an inherent preference toward nature-friendly environment. [15] compared the restorative value of four types of landscape environments (urban, mountain, forest, and water) using questionnaires and fMRI as well, and found the water type was a most restorative environment among other stimuli.

Many EEG studies in aspects of environment have engaged with showing generally beneficial effects of green spaces or specific colors and environments in deriving preference or restorative effects from natural landscape. However, there was no research regarding its beneficial effect on nightscape. Accordingly, this study used EEG to evaluate nightscapes related with its fear and settings (natural versus built landscape). Not only these landscape type but also appearance of an adult on each image compared in this to verify the EEG's usability in landscape evaluation field.

Table 1. Related research and its experimental environments

Researchers	Experimental settings	Used brain waves
[6]	Wildness landscape (Extensive landscape, small environment, and abstract landscape)	Alpha
[21]	Emotional color settings	Alpha and Beta
[11]	Landscape and urban scenes for the restorative potential	Alpha, Beta, Delta, and Theta
[23]	Various deciduous broad-leaf forest	Alpha, Beta, Delta, and Theta

[28]	Varing locations and vegetation density in natural landscape	Alpha
[10]	Built urban environment and an urban green space environment (8 different settings)	Levels of excitement, engagement, and frustration (as interpreted by proprietaty EEG software)

1.4. Research hypotheses

Based on the purposes and literature review, the following four hypotheses examined in this paper.

- H1: People's level of fear will be lower in NNIG than BNIG.
- H2: The presence of a person in nightscape settings will affect rated fear and EEG.
- H3: The relative alpha and beta wave of EEG will vary depending on presence of a person and nightscape type.
- H4: The research subjects' EEG response parameters would correlate with their reported level of fear when viewing the nightscape settings.

2. Methods and Data

2.1. Participants

A total of 40 students, professors and staffs from various departments at Virginia Tech participated in this study. They were assigned randomly to one of two groups: built nightscape image group (BNIG, n=20), and natural nightscape image group (NNIG, n=20). Among them, 23 were men and 17 were women. Participant' age ranged from 20 to 40 (52% were in their twenties, 36% in their thirties, and 12% in their forties). Our research protocol and survey instrument were approved by the Institutional Review Board of Virginia Tech.

2.2. Experimental Images

In order to verify these assumptions, twelve digital photographs were used to conduct surveys at the same time as the EEG experiments. There was a discussion about the elicitation work to select these photo settings with five experts who are professors majoring in landscape architecture, architecture, and urban planning.

The six sets of photos used in this study were taken during the same season at the Virginia Tech campus. We identified two core environments of nightscape each with a three of photographs: 'built' (or 'grey) scenes (i.e. buildings, roads, walls etc.) as the built nightscape images and 'green' scenes (fields, forest, parkland) as the natural nightscape images. Also each set has two photos, one with an adult figure and another one without an adult figure. As participants view each image, they were asked to rate the level of fear elicited by the nightscape on a 7-point Likert-type scale (where 1 = very fearful, and 7 = very safe). The examples of the experimental images are below (Figure 1), and all of stimuli used in this study are depicted in Appendix A.

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(**a**) (**b**)

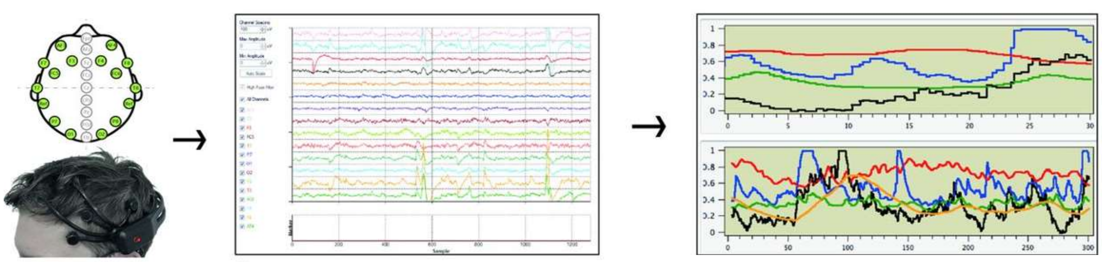
Figure 1. The examples of experimental images taken by the authors: (**a**) natural scene without an adult; (b) built scene without an adult.

2.3. Apparatus (Emotiv EPOC EEG device)

We selected the Emotiv EPOC EEG device in this study (see in Figure 2). The Emotiv Epoc headset was used to extract the EEG data from each participant. Visual stimuli were presented on a 19-inch LCD monitor. Using the Emotiv Test Bench and OpenVibe as software, we captured the raw EEG output coming from the headset. This headset has 14 electrodes (saline sensors) that take readings from activation sites on the surface of the brain, and comes with a suite of software packages. It also includes a 2-axis gyroscope to detect the wearer's head motion and orientation (see details in Figure 3).

Figure 2. Emotiv EPOC EEG device used in this study

[1] Reference: [29]



(**a**) (**b**) (c)

Figure 3. Process of collecting EEG data: Emotiv EPOC records EEG signals from 14 sensors position according to the 10-20 international system: Row EEG [(a) The electrodes location] signals are then 'translated' and classified in four different emotional states; (b) Output from Emotiv; (c) Output using Testbench software from Emotiv Control Panel and Affective suite (EEG data belongs to the authors).

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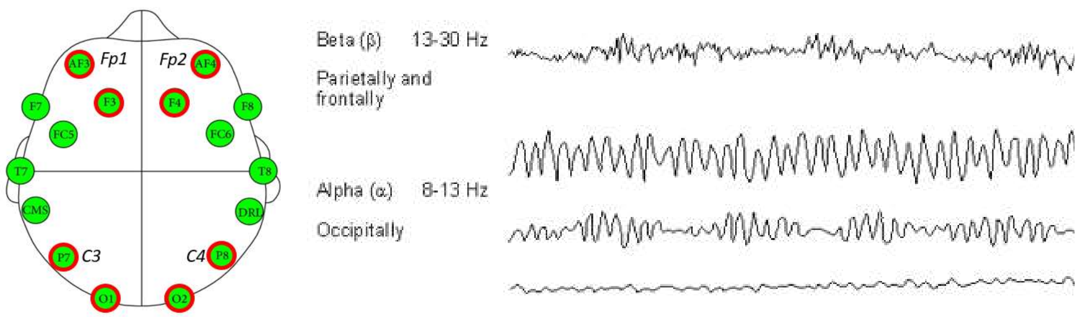
[1] Reference: [29, 30]

2.4. Measurements (EEG)

In order to remove the residuals from the EEG original data, we performed Fast Fourier Transform (FFT) after filtering and then conducted PSA (Power Spectrum Analysis). From this step, the absolute power value and the relative power value for each frequency were derived. The relative power value means a power value that equal to an absolute value difference between individuals. This represents the sum ratio of the frequency set for the total sum of the entire frequency ranges in the power spectrum. Previous studies have indicated that the EEG signal may be different for individuals and environments. That is, even when the external conditions such as temperature and brightness are measured in the same way, the electric resistance varies depending on the state of the scalp and the state of the mental state, so the result of EEG may be different.

Among 12 channels of EEG, we used the main 8 channels from frontal (Fp1, Fp2, F3, F4), and occipital (O1, O2) and parietal (C3, C4) in order to capture two main waves; Alpha and Beta power. The alpha power (8-12.99 Hz) appearing when relaxing [6, 28] and the beta power (13-29.99 Hz) appearing when being anxious or stressed [23, 21, 11] were extracted and analyzed among various types of brain waves. We also used and analyzed the relative power, which is the whole interval of the alpha and beta power, to determine the EEG differences between the participants.



(**a**) (**b**)

Figure 4. EEG measurements: (**a**) The main 8 EEG areas used in this study (marked with a red boundary); (**b**) EEG rhythms; The frequency of Alpha power (bottom in the figure) and Beta power (above in the figure).

[1] Reference: [29, 31]

2.5. Statistics

All of data we tested were analyzed by using SPSS 15.0. One-way ANOVA was carried out to verify fear result and changes by frequency ranges of EEG depending on different environment settings [with adult figure in BNIG (1), without adult figure in BNIG (2), with adult figure in NNIG (3), and without adult figure in NNIG (4)]. After the ANOVA test, we performed a Post-doc (Scheffe) to identify the specific differences between the groups.

3. Results

3.1. Self-reported Level of Fear

The results of the fear rating for each nightscape image is as follow (Table 2 and Figure 5). Compared with the mean between two groups, the level of fear tended high in BNIG in general. BNI without adult figure rated the highest fear among four types of landscape images. On the other hand, the lowest fear was in NNI without adult figure.

Table 2. Self-reported level of fear

BNIG (n=20)		NNIG (n=20)	
With adult figure	Without adult figure	With adult figure	Without adult figure
4.60±1.07	5.60±1.65	4.80±1.40	4.40±1.51

[1] BNIG: Urban nighttime image group, NNIG: Landscape nighttime image group.

[2] values are presented as mean±SD

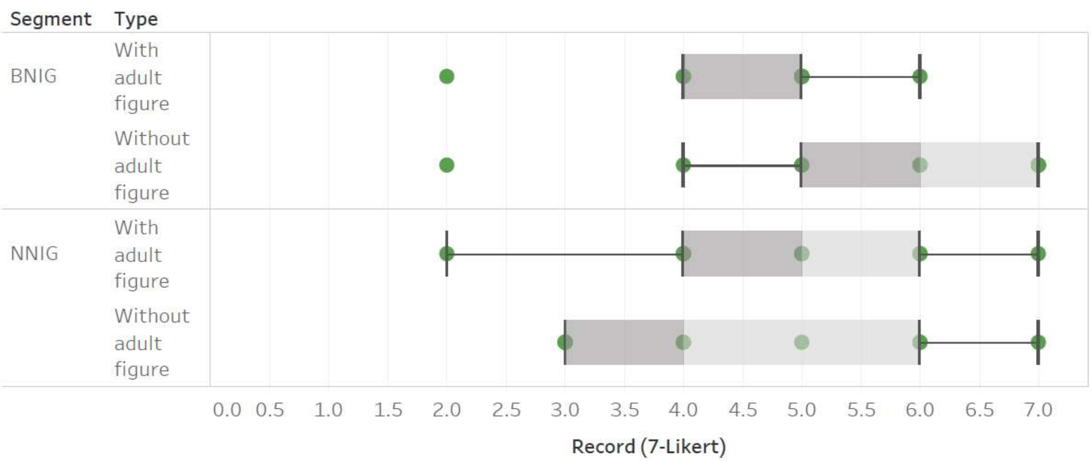


Figure 5. Box plot chart of Fear result depending on four environment settings (using Tableau software)

Table 3. The result of ANOVA depending on landscape types

	Sum of Squares	df	Mean Square	F	Sig	Scheffe's Post hoc
Between Groups	11.561	3	3.854	9.351	.000**	BNIG/wo > BNIG/w** BNIG/wo > NNIG/wo** BNIG/wo > NNIG/w*
Within Groups	31.322	76	.412	-	-	
Total	42.883	79	-	-	-	

[1] **p<0.01, *p<0.05

[2] Only significant results on post hoc were displayed; /wo indicates without an adult and /w indicates with an adult.

Table 3 indicated the results of one-way ANOVA, which suggested the significant differences toward perceived fear between four different landscape settings. For Scheffe's post hoc test, BNIG without an adult was statistically different with all of other settings. In summary, the landscape type and an adult appearance affected peoples' perceived fear generally. Recorded fear average in NNIG was lower than BNIG, but an adult appearance was more influential on perceiving fear than landscape type.

3.2. Changes in EEG

3.2.1. Comparison between groups for EEG on relative alpha power

The averages of relative alpha power were compared with eight types electrode (see Table 4). The results of BNIG showed alpha power ratio increased in Fp1 (0.19→0.32), Fp2 (0.11→0.12), and F3 (0.22→0.34), F4 (0.23→0.32), C3 (0.26→0.34), C4 (0.31→0.36), O1 (0.25→0.29), and O2 (0.21→0.29) after seeing figure including adult. The ratio of NNIG also decreased over the whole electrode areas [Fp1 (0.32→0.26), Fp2 (0.32→0.28), F3 (0.38→0.35), F4 (0.38→0.33), C3 (0.40→0.34), C4 (0.39→0.29), O1 (0.30→0.22), and O2 (0.26→0.24)].

Table 4. Comparison between groups for EEG on relative alpha power

	BNIG (n=20)		NNIG (n=20)	
	Without adult figure	With adult figure	Without adult figure	With adult figure
Fp1	0.19±0.11	0.32±0.03	0.32±0.11	0.26±0.07
Fp2	0.11±0.04	0.12±0.04	0.32±0.14	0.28±0.11
F3	0.22±0.08	0.34±0.13	0.38±0.10	0.35±0.12
F4	0.23±0.11	0.32±0.14	0.38±0.11	0.33±0.16
C3	0.26±0.10	0.34±0.18	0.40±0.09	0.34±0.14
C4	0.31±0.19	0.36±0.15	0.39±0.11	0.29±0.14
O1	0.25±0.11	0.29±0.12	0.30±0.05	0.22±0.06
O2	0.21±0.09	0.29±0.12	0.26±0.11	0.24±0.09

[1] values are presented as mean±SD

Table 5 showed the ANOVA for Alpha power by each electrode. The results described that there were significant differences on Fp1, Fp2, F3, F4, C3, and O1 depending on landscape types. Scheffe's post doc explains which specific groups on each electrode were statistically different. Especially, BNIG/wo type mostly lower than other electrode. Specific significant differences on Scheffe's post hoc are shown on the right side of Table 5.

Table 5. The result of ANOVA for relative alpha power depending on landscape types

Electrode	F	Sig	Scheffe's Post hoc
Fp1	10.713	.000**	BNIG/wo < BNIG/w**, BNIG/wo < NNIG/wo**
Fp2	29.216	.000**	BNIG/wo < NNIG/wo**, BNIG/wo < NNIG/w**, BNIG/w

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			< NNIG/wo**, BNIG/w < NNIG/w**
F3	8.488	.000**	BNIG/wo < BNIG/w*, BNIG/wo < NNIG/wo**
F4	4.397	.007**	BNIG/wo < NNIG/wo**
C3	4.069	.010*	BNIG/wo < NNIG/wo*
C4	1.917	.126	-
O1	3.266	.026*	NNIG/w < NNIG/wo*
O2	2.131	.103	-

[1] **p<0.01, *p<0.05

[2] Only significant results on post hoc were displayed; /wo indicates without an adult and /w indicates with an adult.

3.2.2. Comparison between groups for EEG on relative beta power (unit: mV)

The mean and standard deviation of the relative beta power by eight EEG areas are shown in Table 6. We focused on the difference between before and after an adult appearance by two different landscape settings. The results of BNIG showed most of alpha power ratio increased in Fp1 (0.56→0.66), Fp2 (0.57→0.69), and F3 (0.36→0.39), F4 (0.38→0.44), O1 (0.30→0.31), and O2 (0.30→0.34) except for C3 (0.27→0.24) and C4 (0.24→0.23) after seeing figure including adult. The ratio of NNIG decreased over the whole electrode areas [Fp1 (0.58→0.72), Fp2 (0.59→0.71), F3 (0.34→0.42), F4 (0.35→0.45), C3 (0.17→0.23), C4 (0.14→0.20), O1 (0.26→0.29), and O2 (0.27→0.30)].

Table 6. Comparison between groups for EEG on relative beta power

	BNIG (n=20)		NNIG (n=20)	
	Without adult figure	With adult figure	Without adult figure	With adult figure
Fp1	0.56±0.15	0.66±0.08	0.58±0.16	0.72±0.10
Fp2	0.57±0.15	0.69±0.12	0.59±0.17	0.71±0.12
F3	0.36±0.11	0.39±0.10	0.34±0.14	0.42±0.11
F4	0.38±0.14	0.44±0.10	0.35±0.16	0.45±0.11
C3	0.27±0.15	0.24±0.11	0.17±0.08	0.23±0.12
C4	0.24±0.12	0.23±0.11	0.14±0.09	0.20±0.11
O1	0.30±0.13	0.31±0.09	0.26±0.08	0.29±0.06
O2	0.30±0.13	0.34±0.11	0.27±0.14	0.30±0.06

[1] values are presented as mean±SD

The result of ANOVA for Beta power by each electrode was depicted in Table 7. Unlike Alpha power's ANOVA test, statistical significance was relatively low. For Fp1, Fp2, and C4, there was significant differences depending on landscape types. The value of BNIG/wo was lower than NNIG/w and NNIG/wo was lower than NNIG/w in Fp1. For Fp2's post hoc, there was significant differences (NNIG/wo < NNIG/w). Lastly, C4's result showed NNIG/wo was lower than BNIG/wo.

Table 7. The result of ANOVA for relative beta power depending on landscape types

Electrode	F	Sig	Scheffe's Post hoc
Fp1	6.916	.000**	BNIG/wo < NNIG/w**, NNIG/wo < NNIG/w*
Fp2	3.405	.022*	NNIG/wo < NNIG/w*
F3	1.813	.152	-
F4	2.509	.065	-
C3	2.340	.080	-
C4	3.830	.013*	NNIG/wo < BNIG/wo*
O1	.926	.432	-
O2	.526	.666	-

[1] **p<0.01, *p<0.05

[2] Only significant results on post hoc were displayed; /wo indicates without an adult and /w indicates with an adult.

Figure 6 showed the general comparison depending on four landscape settings by brain wave (Alpha and Beta power). In Alpha power, the dispersion between eight electrodes was relatively smaller than the Beta power. NNIG/wo in Alpha power has the highest value, and overall NNIG value is higher than Beta power. On the other hand, the comparison of Beta power depending landscape types shows that the appearance of an adult has a tendency to be influenced more than the landscape element (e.g., natural element and built element).

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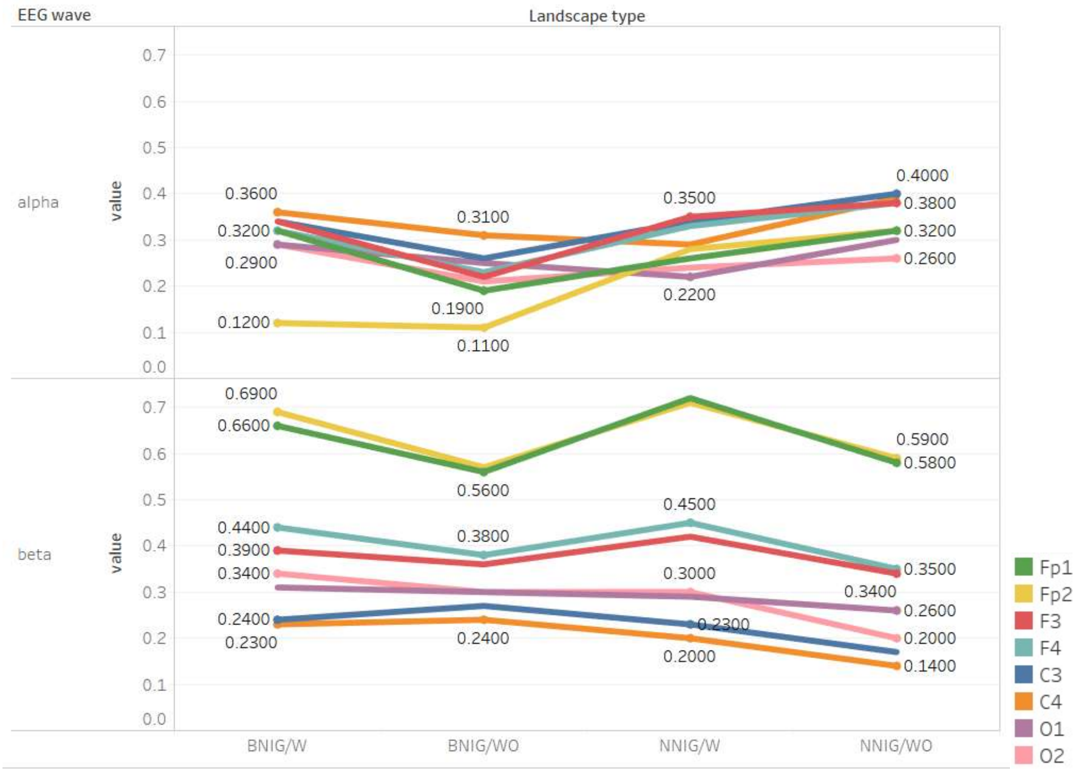

Figure 6. Comparison between groups for EEG on relative alpha and beta power; /wo indicates without an adult and /w indicates with an adult (using Tableau software).

4. Discussion

4.1. Usability of EEG in Landscape Evaluation

This study analyzed the relationship between EEG and fear dependent upon various nightscape settings. We analyzed the relative alpha and beta power depending on four types of nightscape settings including interpreting recorded fear on each nightscape settings from 40 participants. We focused on the differences not only on nightscape settings (BNIG and NNIG), but also presence of adults. The reasons we used the relative alpha and beta power among various types of EEG wave was that alpha is known to occur when one is feeling stable and relaxed while beta is known to occur when one is concentrating. Therefore, it was assumed that there will be a negative relationship between fear and alpha power and positive relationship between fear and beta power. We also assumed that the alpha and beta power will vary depending on the presence of an adult in each nightscape setting. The results of this study is summarized as follows.

First, our results showed that the most fearful nightscape setting was recorded in BNIG without the adult figure when comparing self-recorded fear depending on four types of nightscape settings. In NNIG, on the other hand, the nightscape setting with adult figure was more fearful than the nightscape setting without adult.

Second, overall EEG wave (eight brain areas in alpha and beta power) was affected by not only nightscape type, but the presence of an adult. Especially, it should be pointed out that EEG response in frontal lobes, which is related to the cognitive function, showed a significant relationship between the self-reported fear. The result of relative alpha power indicated that there was a significant difference in Fp1, F3, and O3 brain areas according to a presence of adult. This means the relative alpha power is affected by the presence of people. The result of Fp2 showed there are clearly differences if the setting built or natural. All of brain activity was increased in NNIG compared to BNIG when only comparing settings. As reported, the alpha power increased primarily when the test subject felt relaxed. Hence, decreased alpha power values mean that the brain has changed to a tension and excitement state, so this can be quite related to state feels fear. This is consistent with the self-reported fear in which fear level decreased in with an adult figure on BNIG and increased fear level in with an adult on NNIG. Several brain activities in the relative beta power including Fp1, Fp2, and C4 showed the significant difference. Specifically, the differences in Fp1 showed BNIC/wo was lower than NNIG/w and NNIG/wo was lower than NNIG/w, which means the setting and the presence of an adult as well affect people's brain activity. Overall result on beta power indicated that if there was an adult in setting, the relative beta power increased. This implies there is no direct relationship between beta power result and self-reported fear. The beta power is generally divided into slow beta power (13-21 Hz) and fast beta power (22-30 Hz). Beta power commonly increased during the task requiring attention compared to the relaxed state, and activated beta power reflects an increase in cognitive function due to high intensity information processing activities. Accordingly, it is supposed that increasing beta power in setting with an adult tells people consciously judges they can be threatened by an adult in nightscape setting. We have found that beta power increases when paying more attention, while alpha power decreases depending on nightscape type in this study, and this result is consistent with previous research [11].

4.2. Nightscape Design

Currently there have been very few studies regarding nightscape design while daytime landscape design studies [32] continues to be analyzed. Studies related to existing nightscape studies have been mainly focused on light itself [33, 34] or images on nightscapes [35, 36]. The nightscape, complete with awe-inspiring atmospheric events and potentially restorative fascinating stellar views, requires more empirical investigation [37]. Nightscape design is closely related to preference, satisfaction, and light pollution as well as perceived fear. Therefore, we invite other analysts in the field of nightscape design to extend our findings. Communication between landscape designers and people experiencing the environment at night, as our results suggests, can improve the quality of nightscape. The insight obtained in this study regarding nightscape design is green element such as parks, shrubs, trees, flowers, etc. functions to reduce fear and facilitate relaxation more than built elements. It is also important to consider the significant differences between nightscape settings through EEG which implies its usability in nightscape study, especially for nightscape design. This study has limitation due to the relatively fewer landscape types investigated. We posit that this could be extended in future studies. Recent researches presented the possibility to measure nightscape using sophisticated technology (e.g., airborne hyperspectral cameras from [33]). In sum, various studies comparing perceived nightscape and measured nightscape by various tools presents new possibilities for enhancing the quality of nightscapes.

5. Conclusion

This study has analyzed perceived fear and EEG focusing on the changing alpha and beta power of participants in four different types of nightscape settings to suggest its usability in nightscape design. Our findings indicate the corresponding measures of fear vary according to the environmental settings, which are described as follows: (1) the perceived fear depending the four settings was statistically different and the most fearful nightscape setting was BNI without the presence of an adult; (2) the differences of the alpha and beta power depending on settings were significant, which means EEG can be one of the measures for evaluating nightscape characteristics (e.g., fear, preference, etc.). The alpha power recorded relatively high in nightscape settings consisting of natural elements. Additionally, the presence of an adult effects the brain wave (both alpha and beta power) regardless of the nightscape setting.

The approach we employed enables a deeper understanding of the emotional perception and fear among human subjects by identifying the physical environment which impacts how they experience nightscapes. Although more specific nightscape setting should be compared using EEG

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in future studies, our findings based on the physiological EEG experiment provides a new analytic approaches to study nightscapes.

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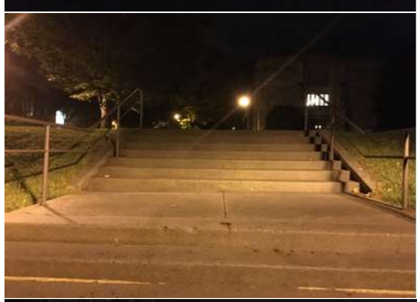
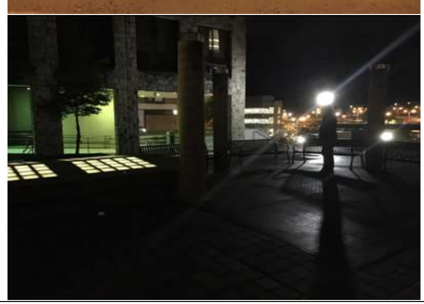
Conflict of Interest: The authors declare no conflict of interest.

Appendix A

	BNI	
Division	Without an adult	With an adult
Type 1		
Type 2		
Type 3		
	NNI	
Type 1		

Type 2

Type 3

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